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THE PRECAUTIONARY APPROACH TO FISHERIES WITH REFERENCE TO STRADDLING FISH STOCKS AND HIGHLY MIGRATORY FISH STOCKS

Explanatory note

The United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, at its second session, held in New York from 12 to 30 July 1993, requested the Food and Agriculture Organization of the United Nations (FAO) to prepare an information paper on the precautionary approach in fisheries management (A/48/479, para. 17 (c)). Pursuant to that request FAO has provided the present information paper.

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I. SUMMARY

1. The present status of many fishery resources around the world indicates that management practices need to be improved and particular attention is required for high seas fisheries. The uncertainty and related risk resulting from intrinsic inefficiencies in fisheries management, insufficient scientific information and natural variability (including climate change) is progressively being recognized and taken into account. An acceleration of the process of evolution of fisheries management and a broadening of its scope are required to take fully into account both the explicit requirements of the 1982 United Nations Convention on the Law of the Sea and those of Agenda 21 of the United Nations Conference on Environment and Development. A global trend is developing in favour of the concept of precaution, which should now also be considered for implementation in fisheries management.

2. The concept of precaution requires management authorities to take pre-emptive action where there is a risk of severe and irreversible damage to human beings and, by extension, to the resources and the environment, even in the absence of certainty about the impact or the causal relationships. When there is doubt about the effect of a technology or fishing practice on the marine environment and resources, preventive or remedial action would have to be taken, erring on the safe side, with due consideration to the social and economic consequences.

3. The need for precaution in management is reflected in two main concepts: the precautionary principle and the precautionary approach. The precautionary principle has suffered from a lack of definition and slack usage leading to extreme interpretations regardless of economic and social costs. It has therefore developed a strong negative undertone. The precautionary approach, which implicitly recognizes that there is a diversity of ecological as well as socio-economic situations requiring different strategies, has a more acceptable "image" and is more readily applicable to fisheries management systems.

4. Precautionary management measures have often been advocated in the past but they have rarely been implemented because of their potential short-term costs. On the one hand, they are needed to improve fisheries management and ensure more sustainable fisheries development, reducing risks for the resources and for fishing communities. For this purpose it is recommended to use more precautionary management reference points than in the past. On the other hand, overly stringent measures could lead to economic and social chaos in the fishing industry.

5. The requirement laid down in the Convention on the Law of the Sea for the "best scientific evidence available" remains the first condition for effective and equitable management and the concept of precaution does not exempt fishing States and management authorities from their responsibilities to build up the necessary scientific information and cooperation. The best scientific evidence could be viewed as the most statistically sound evidence.

6. In a situation of high potential risk and lack or inadequacy of information, the concept of precaution requires that the onus of scientific

proof (e.g., in the form of an environmental impact assessment) be on those who intend to draw benefits from the resource and contend that there is no risk (reversal of the burden of proof).

7. The precautionary approach propounds caution in all aspects of fishery activities: in applied fishery research, in management and in development. It can easily be translated into a "tool-box" of precautionary measures among which appropriate ones can be selected for different situations. It would be consistent with the internationally agreed principles of sustainable development and those of responsible fishing and would, inter alia:

- Promote the collection and use of the best scientific evidence;
- Adopt a broad range of reference points;
- Agree on a set of rules and guidelines;
- Adopt action-triggering thresholds;
- Agree on acceptable (tolerable) levels of impact and risk;
- Improve participation of non-fishery users;
- Improve decision-making procedures;
- Promote the use of more responsible technology;
- Introduce prior consent or prior consultation procedures;
- Strengthen monitoring, control and surveillance;
- Adopt experimental management and development strategies;
- Institutionalize transparency and accountability;
- Re-establish natural feedback controls.

II. INTRODUCTION

8. The review of the state of world fishery resources undertaken by FAO and the global analysis available in the FAO report on the state of food and agriculture show that, although management practice has evolved during the last half century, it has tended to lag behind management theory and that progress towards sustainability, since the first FAO Technical Committee on Fisheries in 1945, has been insufficient. 1/ It is now recognized that the biomass of many important fish stocks is close to or even below the level that could produce the maximum sustainable yield (MSY), leading to resource instability and economic losses. A number of fisheries have collapsed ecologically or economically and the situation in the high seas raises particular concern.

9. The increased recognition that conventional fishery management needed to be improved has been accompanied by a growing concern for environmental management, particularly as a result of the World Conference on Human Environment (Stockholm, 1972), the FAO Technical Conference on Fishery Development and Management (Vancouver, 1973), the FAO World Conference on Fisheries Management and Development (Rome, 1984), the United Nations Convention on the Law of the Sea (hereafter, the 1982 Convention), the work of the Brundtland Commission from 1984 to 1987 (World Commission on Environment and Development, 1987), the United Nations Conference on Environment and Development (Rio de Janeiro, 1992) and the International Conference on Responsible Fishing (Cancun, Mexico, 1992).

10. Moreover, the emerging awareness of the complexity of marine ecosystems and related scientific uncertainty, particularly in the high seas, and of the risk of error in management requires an acceleration of the evolution of fishery management, a broadening of its scope and a change in attitudes. Two important and related requirements of the new management context are the need for more caution and for better inter-generational equity. The latter issue concerns the ethics of renewable resource use and the moral obligation placed on the current generation to exploit the resources and enact conservation measures in such a manner as to preserve options for future generations.

11. The present paper, prepared upon the request of the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, intends to clarify the concept of precaution and its implications in fisheries with particular reference to straddling fish stocks and highly migratory fish stocks. It has been difficult, however, to focus the analysis solely on these two categories for two reasons. One is that the concept of precaution is general and relevant to all types of fisheries. The second is that the management measures applied to the various parts of a transboundary resource must be consistent. This implies that if the nature of a resource requires precaution, it should be provided throughout its distribution range.

12. The following sections provide a review of: (a) the issues related to uncertainty and risk in fisheries and to the need for caution in management; (b) the requirement for, and formal references to, precaution; (c) the precautionary approach to fishery management; (d) the implications for fishery development; and (e) the implications for fishery research.

III. UNCERTAINTY, RISK AND CAUTION

13. In natural ecosystems, the abundance of a predator is controlled by the abundance of its prey. Excessive predation results in a decrease of the prey abundance and thus a higher mortality and lower fecundity of the predator with, as a consequence, a decrease in its own abundance and predation rate (feedback control). In ecological terms, fisheries are organized predators. As such, their survival depends on the survival of their living resources and they are far more sensitive to natural feedback control than other industrial systems such as those using oceans as a waste dumping area. However, contrary to natural predators, fishermen do not receive sufficient feedback control through signals of resource stress. Their operations are primarily independent of the natural resource ecosystem and, indeed, are protected from such feedback

controls by price increases (as resources become scarcer) and governmental subsidies. They can therefore continue and even expand despite the environmental and resource degradation they may produce. In many areas, this has led to resource erosion, economic losses and social disruptions that illustrate the fisheries management risk and reflect behaviour which in the last decades has been neither sufficiently responsible nor precautionary.

14. Caution is usually required to avoid unwanted effects or limit their probability of occurrence. There is no doubt that fisheries, including those exploiting straddling stocks and highly migratory species, have an impact on the ecosystem, reducing species abundance and reproductive capacity, possibly affecting habitats and genetic diversity. The possible impact on endangered species has also been a source of concern. Some impact on the resource base cannot be totally avoided if fisheries are to produce food and development. Moreover, the biological effects of fishery activities are usually reversible and experience has shown that trends in biomass and species composition can be reversed. However, degraded habitats may require long recovery times and higher rehabilitation costs, but this type of impact is negligible in most high seas fisheries.

15. The necessary impact of fisheries would need to be accurately assessed and forecast in order to propose management options reducing to a minimum the possible risk of severe and costly or irreversible crisis. A major problem is that the properties of fishery resources, their "fluid" nature, the poor quality of fishery data, the limitation of scientific models and research funds, the inherent difficulty of research in the high seas and the fluctuations of economic parameters tend to limit scientific understanding of the fisheries ecosystems. This leads to a degree of uncertainty in the scientific, technical, economic and political information upon which managers and industry leaders base decisions which may not always be wholly appropriate. It must therefore be accepted that errors might be made and have been made.

16. Errors may affect: (a) the basic fishery data used for analysis such as on catches, effort, sizes landed, etc. (measurement error); (b) the estimation of populations and parameters derived from such data (estimation error); (c) the understanding of relationships between the different elements of the fishery system and their interaction (process errors); (d) the way these relationships are mathematically represented (model error); (e) decisions that management takes on the basis of such information (decision error); and (f) the way in which management measures are implemented (implementation error). These errors can lead to two types of situation, where:

(a) Management measures should have been taken but were not and, as a result, the resource is damaged. There are short-term costs for the resource and, possibly, for the fishing community if not compensated by government subsidy. The biological impact is usually reversible if a corrective measure is applied, except perhaps in the case of major damage to the habitat. This type of error may also carry the risk of major economic consequences (as in Peru or, more recently, in Newfoundland);

(b) Management measures may be unnecessarily taken and fishing activities curbed. The cost of the error is borne by the fishery. The biological effects

are usually reversible soon after the measure is suppressed. The socio-economic impact may or may not be reversible (e.g., where there is loss of market).

17. Raising research standards to reduce substantially the risk of error and the level of uncertainty implies requirements for data and financial resources which would often be unrealistic, particularly for high seas resources. It must therefore be recognized that management decisions dealing with actual problems or perceived risks will often be necessarily taken with less than complete and accurate information. A fishery management strategy aiming at no risk at all for the resource and the communities would imply either research costs beyond the value of the fishery or no development at all (in the case of an extreme interpretation of the concept of precaution). Few Governments would find either of these two extreme options viable. Cautious management will therefore deal explicitly with risk and aim at a compromise and it should be clear that the higher the uncertainty and/or risk the greater will be the need for caution, particularly in the selection of management reference points. 2/ An important and difficult task for cautious management authorities will be to promote decisions about the levels of impact (and risk) that are acceptable (tolerable) to society.

18. Particular caution may be necessary when resources and people are in a highly vulnerable situation. This is true, for example, of small island countries where the erosion of natural resources may lead to the degradation of the reef ecosystem and, beyond a certain threshold, to breakdown of development opportunities, life support and social order.

IV. THE REQUIREMENT FOR PRECAUTION

19. The Shorter Oxford English Dictionary defines precaution as "caution exercised beforehand to provide against mischief or secure good results. Prudent foresight. A measure taken to ward off an evil." In environmental management, the meaning generally given to precaution is that of acting in advance to avoid or minimize negative impact, taking into account the potential consequences of being wrong.

20. The concept of precaution seems to have become an important factor in negotiations between States to establish management measures in circumstances where there is an obligation to negotiate in good faith to reach agreement (e.g., with respect to straddling stocks under the 1982 Convention or high seas fishing). Given the wide support for this concept in environmental law, a State which refers objectively to it will hope that it cannot be accused of bad faith.

21. In fisheries, the concept of precaution has been expressed as "the precautionary principle" (hereafter, the principle) or "the precautionary approach". Although the two terms relate equally well to the concept of caution in management, they are differently perceived. The first, because of slack usage, has developed a negative undertone. Radically interpreted, it has sometimes led to an outright ban of a technology and is sometimes considered incompatible with the concept of sustainable use. The second is apparently more generally acceptable because it implies more flexibility, admitting the

possibility of adapting technology, consistent with the requirement for sustainability.

A. The precautionary principle

22. The precautionary principle requires authorities at entrepreneurial, national, regional and international levels to take preventive action when there is a risk of severe and irreversible damage to human beings by technology. Its most characteristic attribute is that, in these circumstances, action is required even in the absence of certainty about the damage and without having to wait for full scientific proof of the cause-effect relationship. In addition, when there is disagreement on the need to take action, the burden of providing the proof is reversed and placed on those who contend that the activity has or will have no impact.

23. The principle has been referred to and applied at the national level in relation to human activities with potentially severe effects on human health (engineering, the pharmaceutical and chemical industries, nuclear power plants, etc.). In international environmental law, the principle has emerged as a recognition of the uncertainty involved in impact assessment and management, particularly in the determination of the immediate and future consequences and associated costs of current decisions for human health, for our resources and for the environment.

24. In the 1970s, following the 1972 Stockholm Conference, concern for human safety was progressively extended to the human environment and to other species. This led to increasingly frequent reference to the principle in international agreements and conventions, often with limited analysis of its practical implications. The principle has been invoked in issues related to the ozone layer, the greenhouse effect and the conservation of nature. It has touched indirectly on fisheries through provisions in the international conventions on dumping at sea (the Paris and Oslo Conventions, Marpol) relating to pollution by fishing vessels.

25. The Declaration of the 1987 International Conference for the Protection of the North Sea contains an example of the concept of precaution in relation to coastal States' jurisdiction, habitats, species and fisheries, including pollution from ships. It provides that "States accept the principle of safeguarding the marine ecosystem by reducing dangerous substances, by the use of the best technology available and other appropriate measures" and that

> "This applies especially when there is reason to assume that certain damage or harmful effects on the living resources are likely to be caused by such substances and technologies, even where there is no scientific evidence to prove a causal link between practices and effects."

26. General Assembly resolution 44/225 of 22 December 1989, on large-scale pelagic driftnet fishing and its impact on the living marine resources of the world's oceans and seas, could be considered a case of radical application of the concept of precaution, despite the lack of explicit reference to the principle. The resolution expressed concern about the size of the fleets, the

length of the nets, their mode of operation, their potential impact on anadromous and highly migratory species, their by-catch and the concern of coastal countries on the state of resources close to their exclusive economic zones. It recommended that a worldwide moratorium should be imposed on all driftnet fishing by 30 June 1992 and it established a set of immediate and regionally tailored interim measures. It also provided that such measures would not be imposed in a region or, if implemented, could be lifted, should effective conservation and management measures be taken upon statistically sound analysis to be made jointly by concerned parties.

27. There is no explicit reference to the principle in the 1982 Convention. Part XII, on "Protection and preservation of the marine environment", does not contain detailed instruments for implementation of the conservation of the marine ecosystem, but it does state in a global instrument, in article 192, the following general obligation: "States have the obligation to protect and preserve the marine environment." In addition, ecosystem conservation also requires measures for the fisheries sector, striking a balance between the provisions for environmental conservation and fisheries management to ensure sustainable exploitation.

28. Fisheries mismanagement is unlikely to threaten the future of humanity and as a consequence radical interpretations of the principle may rarely be justified. Of particular relevance in this respect is the fact that, in its Rio Declaration, as well as Agenda 21 (chap. 17, on protection of the oceans), the United Nations Conference on Environment and Development (UNCED, 1992) referred to the need for a precautionary approach and not to the principle itself.

B. The precautionary approach

29. UNCED stressed the need for a precautionary approach to ocean development in its Rio Declaration and in Agenda 21, particularly in its chapters on the management of coastal areas, resources under national jurisdiction and high seas resources. The following wording, which superficially resembles that of the principle, is subtly different in that it reflects a softer requirement, recognizing that there are differences in local "capabilities" to apply it and calling for "cost-effectiveness" (i.e., taking into account economic and social costs):

> "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation." (Principle 15 of the UNCED Rio Declaration)

30. The FAO Technical Consultation on High Seas Fishing (Rome, April 1992) addressed the issue. Taking note of the precautionary approach recommended by UNCED, it agreed that fisheries should be managed in a cautious manner but stressed that precautionary management did not necessarily require moratoriums.

31. At its first substantive session, held at New York in July 1992, the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks also addressed the issue. It could not reach consensus on the precautionary principle, which many countries equated with a moratorium on fishing and considered too radical for such environmentally soft industries as fisheries. A consensus developed instead on the need to introduce or strengthen the precautionary approach to fishery management. The Inter-American Conference on Responsible Fishing (Mexico City, 1993) also referred to the need to take precaution into account in the Code of Conduct on Responsible Fishing, to be prepared by FAO.

32. Another example of the precautionary approach is given by the form in which the Advisory Committee on Fisheries Management (ACFM) of the International Council for the Exploration of the Sea (ICES) delivers its advice to its member States:

> "For stocks where, at present, it is not possible to carry out any analytical assessment with an acceptable reliability, ACFM shall indicate precautionary total allowable catches (TACs) to reduce the danger of excessive efforts being exerted on these stocks."

33. The implicit assumption is that in the absence of scientific assessments, uncontrolled fisheries are likely to build up overcapacity and overfish the resources. The preventive action is to establish TACs at conservative levels to limit fishing until better assessments become available. The implication is that such conservative measures would be lifted only if better information were provided.

34. In general, the precautionary approach is intended to promote a more equitable balance between short-term considerations (which lead to overfishing) and considerations of a longer-term nature. It also seeks to promote a more equitable balance between the attention given to the needs of present and future generations. Such an approach would address the issue of inter-generational equity (as required by UNCED) and would tend towards reducing the cost of our present decisions for future generations. By comparison, and despite the fact that it aims at sustainability, conventional fishery management addresses primarily, and rather inefficiently, the issue of intra-generational equity and allocation of resources between present users. In the absence of explicit reference to social and economic costs to fisheries, the concept of precaution could lead to imbalance in favour of non-fishery uses and future generations.

35. The concept is also intended to counteract the effects of current high economic discount rates which provide a strong incentive to overfish, maximizing the discounted net benefits from a stock and de facto preferring present consumption over future consumption. 3/ As these rates increase, they prejudice supplies to future generations which the precautionary approach is intended to protect.

36. Moreover, fisheries authorities and industry should not only consider the need to apply the concept of the precautionary approach to their own activities, but should also encourage its use by others whose activities damage the oceans' productivity and the livelihood of fishing communities.

V. THE PRECAUTIONARY APPROACH TO FISHERIES MANAGEMENT

37. Precautionary measures for fisheries management have long been advocated as a means to avoid crises and higher costs to society. These have not often been applied in practice because much attention has been paid to short-term costs while longer-term benefits have not been properly valued. Effective action is needed through which fisheries management should move progressively towards more risk-averse exploitation and management. What is new in the modern requirement for precaution is not so much the sort of management measures that are implied but the way in which such measures should be implemented (i.e., automatically enforced with no exceptions) and when they should be implemented (i.e., as soon as a serious and potentially irreversible effect is detected).

38. An extreme interpretation of the concept of precaution, leading to unnecessarily stringent and costly measures, would rapidly become counter-productive by deterring fishery authorities from using it as widely as possible. The problem is therefore one of promoting effective caution in fisheries to the point where the risk of an irreversible impact on the environment and resources will be reduced below the level which would call for drastic measures with potentially irreversible damage to the fishery sector and the coastal communities. This could be achieved by exerting caution systematically, at all levels of the management process, to reduce substantially the risk of errors.

39. It is often supposed that preventive approaches to management are more precautionary than reactive ones because they anticipate unwanted events through knowledge of the system. A strong and unwarranted assumption behind such suppositions is that there is enough knowledge to allow such events to be reliably anticipated and avoided. Unfortunately, fishery systems are not fully predictable and errors are always likely. As a consequence, a precautionary management strategy would need sufficient preventive capacity to avoid predictable problems with enough reactive (corrective) capacity, flexibility and adaptability to ensure a safe "trial-and-error" process as knowledge about how the system works is collected. Elements to be included in such a strategy are given in section D below.

40. For the same reason, it is not always prudent to rely on deterministic pseudo-quantitative reference points of dubious precision for a target-oriented management (e.g., based on TACs and quotas). More precautionary strategies would recognize the uncertainties in the data and promote adaptability and flexibility through appropriate institutions and decision-making processes. These will rely not only on expert advice but also on people's participation. In doubtful cases, decisions should "err on the safe side" with due regard to the risk for the resource and the social and economic consequences.

41. A precautionary approach to fisheries management implies agreement on action to be taken to avoid a crisis as well as action required if such a crisis occurs unexpectedly. Agreement on such action, at an international level, implies the existence of agreed standards, rules, reference points, critical thresholds and other criteria. It also implies international consensus on acceptable levels of impact.

A. Management standards, rules and reference points

42. Better quantification and qualification are required for such widely used subjective terms as detrimental, harmful and unacceptable impacts, which are generally used in expressions of the need for precaution. One of the major tasks for research and management is to develop agreement on standards, rules, reference points and critical thresholds on which to base decisions and meet the management requirements of the 1982 Convention and Agenda 21, for the various types of ecosystems and resources.

43. Rules which would be over-restrictive or used without a clear understanding of their practical implications will not lead to consensus on the need for the general application of a precautionary approach. It must also be recognized that because of the generality of conservation principles and the transboundary nature of many resources, rules established for the management of straddling stocks and highly migratory species are likely to be required in the near future for the resource management of exclusive economic zones.

44. The implication is that, although it is likely that only biological criteria can be internationally agreed for transboundary resources, it is in the interest of all coastal States to consider also their potential social and economic consequences if generalized to exclusive economic zones. The following list gives some examples of principles or rules that have been proposed in the literature with a view to illustrating both the need for them and the difficulty of defining them in realistic terms:

(a) Fisheries should not result in the decrease of any population of marine species below a level close to that which ensures the greatest net annual increment of biomass;

(b) Fisheries should not catch amounts of either target or non-target species that will result in significant changes in the relationship among any of the key components of the marine ecosystem of which they are part;

(c) The mortality inflicted on any target or non-target species is unacceptable if it exceeds the level that would, when combined with other sources of mortality, result in a total level that is not sustainable by the population in the long term;

(d) Fish management authorities should set target species catch levels in accordance with the requirement that fishing does not exceed ecologically sustainable levels for both target and non-target species.

45. The first principle implies that populations should not fall below the level of abundance corresponding to MSY, where their annual rate of biological production (turnover) is the highest. This is in line with the 1982 Convention requirements. It has been repeatedly shown, however, that it is often inadvisable to try to extract the MSY from a resource. Moreover, for multi-species fisheries, this principle would require that all species be exploited below their MSY abundance and therefore that the overall level of exploitation be fixed at the lowest level required by the species with the lowest resilience, reducing drastically the utility of the resource. 4/

46. The second principle implies that fishing will not "significantly" disturb the food chain without guidance on how to judge whether an observed or potential disturbance is significant. Moreover, applying the first principle would lead, in practice, to applying different fishing mortalities to different species and this would lead to a change in relative abundance of species, affecting the food chain. As a consequence, the second principle is difficult to use in practice for many fisheries and may not even be consistent with the first.

47. The third and fourth formulations require that all sources of mortality are taken into account when assessing fisheries impact. These would include natural mortality as well as direct and indirect fishing mortalities (through by-catch, drop-out, damage, etc.), a very demanding task.

48. Assuming that the task is feasible, a problem remains with the vagueness of the term "sustainable" in both formulations. In theory, fisheries are sustainable at various levels of stock abundance and rates of harvesting, but these are not equivalent in terms of risk of recruitment collapse. To be of practical use in fishery management, the concept of sustainability needs to be combined with the notion of risk for the resource, and consequently to the fishing communities. 5/

49. The 1982 Convention states that stocks should not be driven below their MSY level of abundance and this could be considered a bottom-line threshold for stock "sustainability" if expressed in terms of probabilities. New reference points, not foreseen in the 1982 Convention, are required if species sustainability is to be ensured at low risk of collapse. Because of the uncertainty inherent in their determination, these reference points should preferably relate to probabilities. 6/

50. Decision rules could also be established on economic grounds, related, for instance, to fishing capacity: e.g., if capacity increases faster than catches for a given number of years, then some capacity freezing action is taken. If capacity is higher than that required to take the allowable catch by more than a given percentage, then it should be reduced, etc. Other economic reference points could be used but to be employed in the management of straddling and highly migratory stocks, they would have to be general enough to be acceptable to all parties and specific enough to be of practical use.

B. Ecosystem management reference points

51. Ecosystem management is being referred with increasing frequency as the necessary basis ror fisheries management. This requirement is precautionary in nature in the sense that it requires that the integrity and essential functions of the ecosystem must be preserved as a prerequisite to fisheries sustainability. In practice, however, we do not yet know how to manage ecosystems. If the balance between ecosystem components must be maintained, minimizing by-catch or using extremely selective gear, as common sense suggests, might not be the best solution.

52. It has been proposed, for instance, that, in multi-species management, a reasonable strategy would be to exploit all species in proportion to their

abundance in order to maintain the overall ecosystem structure. This is, however, not easy to achieve without wastage of less demanded species; and additional work is certainly required on this matter before objective guidance can be given.

53. New guidelines and reference points are needed for a precautionary approach to ecosystem management, related to global stress indicators, resilience factors, habitat conditions, etc. Measures or scales of ecological stress need to be established and agreed upon if usable reference points are to be provided and effects classified as acceptable/unacceptable from an ecosystem point of view.

54. Clarification is also required, for example, on the measure of "sustainability" for an ecosystem and on the definition of "reversibility" of an impact on it. Ecosystems have a degree of natural variability and can shift from one equilibrium state to another because of natural environmental variability or human stress. Sustainability should therefore not be confused with constancy. As far as reversibility is concerned, fisheries management may be able to suppress unwanted fisheries impacts and rebuild productivity but there is no assurance that the ecosystem could be returned exactly to its "pristine" state.

55. Some of the aims and principles of ecosystem management can be found in the management charter of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and in the 1990 Strategy for Sustainability elaborated by the World Conservation Union (IUCN). These include: minimizing conversion of critical ecosystems to "lower" conditions, compensating habitat conversion with restoration (allowing no net loss), 7/ maintaining ecological relationships, maintaining populations at greatest net annual increment, restoring depleted populations, minimizing risk of irreversible change in the marine ecosystem, etc.

56. Genetic conservation guidelines, when introduced, will make matters even more complicated as management will have to meet conservation requirements at the ecosystem/biodiversity, species and genetic levels. Nevertheless, the definition and analysis of management reference points and the behaviour of stocks and risks attached to those points should be one of the main applied research issues of the next decade if a precautionary approach to management is to be implemented.

57. The above considerations related to standards, rules and reference points demonstrate that a precautionary approach to management requires a thorough scientific effort to develop the scientific tools. Without these the concept of precaution will remain at the level of international rhetoric.

C. Acceptable levels of impact

58. If development and benefits are to be obtained from straddling and highly migratory fish resources, some level of impact has to be accepted. In fisheries, a zero-impact strategy would make no sense. It is therefore necessary to: (a) identify and forecast fishery effects (and risks) accurately

enough, (b) agree on acceptable levels of impact (and risk) and (c) develop management structures capable of maintaining fisheries within these levels.

59. The concept of "acceptable levels of impact" may be related to that of "assimilative capacity" which has generated considerable debate amongst those concerned with environmental protection. The latter implies that nature can absorb a certain quantity of contaminants without significant effect (e.g., the dumping of processed effluents from urban concentrations, radioactive waste, heavy metals and other causes of dramatic and potentially non-reversible impacts). However, with fisheries the problem is different. Fishery resources do possess an assimilative capacity in terms of the fishing mortality they can withstand while still conserving most of their resilience or capacity to return to their original state once the fishery-induced stress is removed. In a way, MSY could be considered a reference point corresponding to the "maximum assimilative capacity" of a stock in terms of fishing stress, a value fisheries should not pass and perhaps even not approach. 8/ The principles listed above imply an acceptable level of impact. The situation becomes more complex when considering the assimilative capacity of a multi-species resource or an ecosystem for which no means of measurement are yet available.

60. An acceptable level of impact (or risk) may be defined as a level which will never be fully accepted (in the sense of definitely approved) but that will be kept continually under review and eventually modified as knowledge progresses. The degree of acceptability of impacts (or risks) will be determined, inter alia, in terms of risk-benefit trade-offs with proper weighting given to long-term needs and natural assets. This requires research capacity to separate the effects of "natural" year-to-year fluctuations and the impacts of fishing from anthropogenic degradation, including global climate change. It requires the development of an effective enforcement capacity to ensure that such levels will be respected. Finally, it requires the establishment of "safety net" arrangements (e.g., in terms of insurance, compensation, etc.) to protect the users and the resource from hazardous occurrences.

61. There is no scientific way of determining objectively what is and what is not acceptable to society. An important prerequisite for the effects of fishing to be acceptable is that they should be reversible if the fishing pressure is reduced or suppressed. It is likely that what may be acceptable to some countries or user groups may not be acceptable to others, and the relevance and importance of traditions and culture should not be underestimated. Science has to provide methods to assess the impacts and objective criteria to help to reach agreement. The difficulty in this regard will not be less than in determining MSY and we should expect considerable scientific argument on the type of impact one might expect and on the level of certainty with which it can be determined. The degree of acceptability of any impact will only be established after intense negotiations between the parties concerned. These are unlikely to proceed easily or rationally if undertaken in a context of crisis. It is therefore advisable to integrate negotiations on impact into the management process before stocks are damaged and before potential socio-economic problems reach an overwhelming level.

D. Practical guidance for management

62. A fishery management policy based on a reasonable interpretation of the concept of precaution should: (a) explicitly adopt the principle of sustainable development as defined by the FAO Conference, 9/ (b) select a set of objectives broadly compatible with it and (c) adopt a precautionary approach based on the following measures:

(i) Use the best scientific evidence available and, if it is not sufficient, invest in emergency research while interim management measures are taken at the level required to avoid irreversible damage;

(ii) Improve information systems. The cost could be covered through fishing fees and will need to be commensurate with the level of risk. All resources, directly or indirectly affected, should be covered. International and regional arrangements should actively promote the development of joint research programmes;

(iii) Adopt a broader range of reference points and management benchmarks more explicitly related to the objectives selected for the fishery and use them to measure the efficiency of the management system (e.g., related to capacity);

(iv) Agree on a set of criteria and rules before a crisis develops. They would be the basis for agreement on the degree of harmfulness of a new fishing technique or practice;

(v) Agree on acceptable levels of impact (and risk) in a process that will identify trade-offs and promote transparency, particularly in relation to public opinion;

(vi) Take into account the combined stresses on resources and environment. Effort reductions may be imposed or special measures affecting fisheries taken when the stock faces unusually unfavourable environmental conditions;

(vii) Manage fisheries in the context of integrated management of coastal areas, raising sectoral awareness about exogenous impacts on fisheries productivity;

(viii) Adopt action-triggering thresholds and management strategies which include pre-agreed courses of action, automatically implemented if the stock or the environment approaches or enters a critical state as defined by pre-agreed rules, criteria and reference points; 10/

(ix) Improve participation of, and dialogue with, non-fishery users, taking all interests into account when developing and managing fisheries. This is required by Agenda 21, necessary for the long-term survival of fisheries and implies improving management transparency and reporting procedures;

(x) Improve decision-making procedures. Decisions by consensus can only lead to ineffective agreement at the level of the lowest common denominator. Introducing voting procedures or using them when they already exist would improve the situation;

(xi) Strengthen monitoring, control and surveillance, thereby improving detection and enforcement capacity (including legal tools), raising penalties to deterrent levels and exerting more vigilant and effective flag State and port State responsibilities;

(xii) Experiment with management strategies and development projects with the support of research. When a risk for the resources is foreseen, the response to possible management strategies and the impact of development projects should be tested on a pilot scale and environmental impact assessments should be conducted.

63. A precautionary approach to fishery management does not require that all of these precautionary measures be implemented in all fisheries at all times. The type of action required and its degree of urgency is a function of the probability of occurrence of a certain type of impact of a certain magnitude, pre-agreed as part of the management scheme, and based on appropriate reference points. Decisions on what should or should not be allowed are comparatively easy when risks are known and extremely high. Proposals to prohibit, even without any scientific background, the use of explosives to fish in the high seas would probably not meet with much international opposition because harmful fisheries techniques (e.g., dynamite and poison) are normally banned by national fisheries legislation. However, deciding whether a 5 per cent by-catch of sharks in a long-line tuna fishery is acceptable would require more careful consideration.

VI. IMPLICATIONS FOR DEVELOPMENT

A. The concept of responsible technology

64. In international environmental law, the principle is often associated with the requirement to use the "best available technology", an obvious parallel to "best scientific evidence available". This wording has sometimes been interpreted as requiring the technology which has the smallest environmental impact, regardless of the short-term socio-economic costs. This interpretation has, however, been contested on the basis that such technology might not always be affordable by all countries and, in particular, by developing ones. 11/

65. General Assembly resolution 44/228 of 22 December 1989 on UNCED referred instead to "environmentally sound technology", stressing the need for socio-economic constraints to be taken into account. The wording does not pretend to limit the choice to a single "best" or soundest technology, implying that many sound technologies may be used together.

66. The Cancun Declaration (Mexico, 1992) provides that "States should promote the development and use of selective fishing gear and practices that minimize waste of catch of target species and minimize by-catch of non-target species".

If social and economic factors are taken into account, in line with the concepts of sustainable development and responsible fishing, the technological requirements should be defined with a view to maintaining (or reducing) the accidental effects of capture and post-capture fishery activities within pre-defined acceptable (tolerable) levels, allowing general application by all countries.

67. In environmental law, technologies are often catalogued on separate lists, the "colour" of which reflects the perceived degree of environmental friendliness. "Black" or "red" lists refer to technologies with unacceptable impacts. "Grey" and "orange" lists refer to technologies usable under some conditions. "Green" lists contain those technologies believed to be harmless or producing only acceptable levels of impact. 12/

68. This approach has been indirectly applied to fisheries by reference to the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979). That Convention gives, in its annex IV, a list of non-selective gear to be banned, which includes all nets. Although it had been designed for migratory birds, the list has been referred to, in Italy, in connection with the banning of large-scale pelagic driftnet fishery. The importance of nets in fisheries and their contribution to the livelihood of small-scale fishermen and indigenous people illustrates the need for careful consideration before referring to lists contained in non-fishery agreements and before elaborating specific lists of fisheries.

69. Considering that, in fisheries, the concept of responsible fishing is well defined and that a Code of Conduct for Responsible Fishing will be adopted, it may be of value to refer to the requirement for "responsible fishery technology" (including capture and post-capture technology) as defined in the Code. Responsible technology will have to be used in all areas of fisheries, including capture, land-based or sea-based processing and distribution. Although some general guidelines can be given, based on known characteristics of types of resources and technology, the most responsible mix of technologies to be used in a particular fishery will be agreed on a case-by-case basis with explicit reference to the agreed management reference points and acceptable levels of impact agreed for that fishery.

70. Moreover, a "better" technology might be theoretically available on the market but in effect not accessible to some countries because of its cost or its sophistication. It is clear that in many instances the general use of the "best technology" will require an improvement in international cooperation in technology transfer, as underscored in Agenda 21. 13/

B. Prior informed consent and prior consultation

71. In dangerous polluting industries, reference has often been made to prior informed consent and prior consultation procedures. The practical significance is that, before introducing a new technology in a controlled or sensitive area, the proponent must produce a substantial amount of information about the technology to be introduced and its potential impact and, eventually, obtain the consent of the other users. 14/ If the introduction is agreed, a number of

specific measures are usually foreseen such as limiting the scale of the initial project, special monitoring and reporting requirements, etc.

72. The general application of prior informed consent or prior consultation procedures to capture fisheries would require further consideration and clarification. 15/ This might be considered for some particularly efficient and potentially dangerous technologies and/or for particularly vulnerable resources or fragile ecosystems when severe, irreversible effects are possible. Prior informed consent of the regional management authority could be required before introducing the new methodology. The procedure may be better accepted if the new technology is patented, limiting the risk that the benefits to the "discoverer" will be jeopardized.

73. In practice, a State proposing to introduce a new technique would be requested to present a report, comparable to an environmental impact assessment. Such an assessment would address potential effects on the target species and on associated species which might be targets for other fisheries in the area or food items for such target species. However, apart from its scientific complexity, it is clear that such impact assessment cannot be conducted in the absence of at least a pilot fishery. The administrative burden this imposes could be overwhelming and the procedure should remain exceptional. The special monitoring and reporting procedures could also be used for activities recognized as unacceptable in the long term and for which phasing out has been decided. Interim reports could be requested during the phasing out period.

74. In the case of high seas areas not covered by any specific international agreement, there would be no competent authority to which the request for prior consent could be made. In addition, there would also be no monitoring or enforcement system in place, making it impossible to detect the introduction of harmful techniques and to measure impact. This is a case where the legal responsibilities of the flag States would need to be clearly determined, especially if the flag State registers all vessels authorized to fish in the high seas as provided for in the 1993 Agreement on the Promotion of Compliance with Conservation and Management Measures by Fishing Vessels in the High Seas.

VII. IMPLICATIONS FOR FISHERY RESEARCH

75. All expressions of the concept of precaution require that "lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation" (principle 15 of the Rio Declaration). The requirement for precaution may therefore appear to require no input from fishery research. In practice, however, the effective implementation of precaution requires substantial support from fishery science, which needs to be adapted to the new requirements.

A. The "best scientific evidence"

76. Prior scientific consensus on cause-effect relationships and potential consequences of fishing has been the basis for cooperation in international fisheries management in the past. It should continue to be one of the most

neutral and peaceful contributions to the resolution of conflict between nations and competing user groups.

77. The Christiania Conference, in 1901, held just before the creation of the International Council for the Exploration of the Sea (ICES), endorsed the principle of scientific inquiry as a basis for rational exploitation of the sea. The same principle was also agreed at the International Conference on the Conservation of the Living Resources of the Sea, hosted by FAO (Rome, 1955). More recently, the 1982 Convention provided that the best scientific evidence shall be taken into account by the coastal State when designing and adopting management and conservation measures in exclusive economic zones (article 61). For the high seas, this Convention provides that measures are designed on such scientific evidence (article 119). More recently, General Assembly resolution 44/225 recognized, in its preamble, that "any regulatory measures ... should take account of the best scientific evidence available".

78. The 1982 Convention does not define the quality of the evidence required in any quantitative manner. The requirement that the evidence should be the best available implies that even poor evidence can be used in designing conservation measures provided it is recognized as the best available. The 1982 Convention does not provide any guidance on how to decide which is "the best" scientific information (see note 16). Nor does it indicate how to operate in the absence of scientific consensus which it implicitly assumes or when no scientific information is available at all.

79. Although the 1982 Convention does not foresee that an existing fishery could be closed if not enough scientific information is available, it does not impose a great burden to be discharged before the necessary conservation measures can be taken. One would assume therefore that, in such a case, the spirit of the Convention is that the missing scientific information should be urgently collected but this does not preclude measures being taken in the meantime. The concept of precaution would ensure that action is not deferred sine die.

80. Concern has been expressed that the principle could imply that scientific facts to back up management decisions were no longer necessary. There is an obvious risk that, by referring to the concept of precaution, scientific objectivity could be less rigorously applied and that international dialogue could be negatively affected. It is hardly debatable that when scientific data are available together with a monitoring and management system, the basic requirement of the 1982 Convention should prevail, and decisions should be taken on that basis. 16/ Emergency action in the absence of scientific consensus should therefore only be justified when there is the risk of severe and irreversible effects and the concept of precaution may be seen as filling the gaps in the 1982 Convention, preventing the absence of scientific data or consensus from opening a loophole leading to "laissez-faire" management and development strategies with damaging or irreversible consequences.

81. In an international fishery management body, a State willing to invoke the need for a precautionary approach in order to promote management measures would have to convince the other parties that exceptional conditions are met for its application: that there is indeed a high risk of severe and irreversible

damage. Science should demonstrate the existence and extent of risk through risk analysis. If the available information was considered insufficient to demonstrate objectively the risk, the application of the concept of precaution could become counter-productive. In such a case the management authority would face "perceived risks", in the absence of objectively demonstrated ones. This is often the case with global societal risks and consensus will have to be achieved through a purely political process involving as much consultation and transparency as possible.

B. The burden of proof

82. In practice, the burden of proof has fallen traditionally on research and management. It has been necessary to demonstrate, with the available data, that harm could be (or was) done to the stock or that fisheries performance could be improved before management measures could be imposed. In many instances, this approach was not effective because fishery research usually lagged behind development. Both the principle and the precautionary approach imply that action might have to be taken without full evidence of the extent of the risk and of the causal relationships.

83. When international consensus on what action to take cannot be obtained because of insufficient information, it has been suggested that the burden of proof be reversed, placing on those who derive benefits from the ecosystem the responsibility to prove that what they intend to do will not lead to "severe and irreversible" effects on the resources. In such a case, the burden of demonstrating that industrial business is conducted in a responsible manner would be on industry.

84. As an example, General Assembly resolution 44/225 recommended a total ban on large-scale driftnet fishing in the absence of scientific consensus on the likely long-term impact, implying that the prohibition of a disputed fishing technique is in order until its acceptability has been demonstrated. It stated that:

> "such a measure will not be imposed in a region or, if implemented, can be lifted, should effective conservation and management measures be taken based upon statistically sound analysis to be jointly made by concerned parties ...".

85. This resolution reversed the conventional course of action, recommending immediate and drastic action (i.e., a total ban of the offending gear) on the basis of international concern assuming that driftnets had an undesirable impact on resources, until shown otherwise. It was agreed that such action could, in principle, be reversed should the joint scientific analysis lead to consensus on the effectiveness of management measures. The resolution, however, gave no guidance or criteria on how to judge the quality or adequacy of the available evidence or the effectiveness of the management measures.

86. The action was confirmed by General Assembly resolution 46/215 of 20 December 1991, which called for action against this type of fishing on the basis that:

> "the international community [has] reviewed the best available scientific data and [has] failed to conclude that this practice has no adverse impact ... and that ... evidence has not demonstrated that the impact can be fully prevented".

87. Another example of reversal of the burden of proof can be found in Council Regulation 345/92 of the European Economic Community (EEC), which regulated the use and the length of driftnets (limited to 2.5 km) in EEC waters. Article 9(a) granted a derogation until 31 December 1993 to some vessels for the use of longer gear, stating that:

> "The derogation shall expire on the above-mentioned date, unless the Council, acting by a qualified majority on a proposal from the Commission, decides to extend it in the light of scientific evidence showing the absence of any ecological risk linked thereto."

88. The concept of reversal of the burden of proof implies that, unless proved otherwise, some fishing techniques may be considered harmful, giving systematically to the resources the benefit of doubt. It may be taken as implying that fishing techniques, which would not be formally authorized in a management area or for a particular species, would be forbidden. The requirement is related to the notion that an environmental impact assessment should be presented before a new technology or practice is introduced in an ecosystem. It is also related to the concept of prior consent or prior authorization discussed in section VI.B.

89. Under this concept, the industry and fishing communities would bear the cost of research and may have to forego some income-generating activities if they are unable to convince the authorities of the acceptability of the technique. It would be fair to give the people whose activity and livelihood are threatened by the measure the opportunity to develop the proof required within a given time span.

90. It is usually impossible to forecast, with any degree of accuracy, the impact that a new fishery will have before it starts and some data are collected. It might therefore be imagined that no new fishery could be developed because evidence of the absence of adverse impact cannot be given by those involved in the venture. A precautionary approach, in such a case, should lead to agreement for a pilot fishery large enough to collect data and build up the scientific evidence required, but small enough to ensure that no irreversible effect is likely. In practice, there will usually be a trade-off: a small amount of risk for the resources being exploited will have to be accepted in exchange for the possibility to provide food and a livelihood for humans.

91. Meanwhile, and in accordance with the precautionary approach, interim precautionary measures may be taken giving due consideration to the actual nature and level of risk for the resource, and to the social and economic costs to the community. Therefore, banning fishing techniques would be extreme measures, justified only when the risk of irreversible damage to the resource or the community is high. It is suggested that wide application of the concept of

reversal of proof in fishery management operations would lead to considerable economic damage and discredit the concept of precaution itself.

C. The role of statistical methods

92. The 1982 Convention does not give any indications on how to determine which scientific evidence is the "best". General Assembly resolution 44/225 required "sound statistical analysis" and this new terminology could be considered an attempt to clarify further the concept of "best evidence", equating it with "statistically sound evidence". The advantage of incorporating statistics into the concept is that it offers a way of using well-established mathematical techniques and tests. It also forces scientists and decision-makers to recognize and measure explicitly the levels of uncertainty and the risks attached to these decisions.

93. Scientists still must agree on which type of statistical methods to use (parametric, non-parametric, geostatistics) and which test is most appropriate for a particular problem. Fisheries do not usually conform strictly to the requirements for unbiased application of conventional statistical methods and the reliability of many statistical tests might still be a matter for debate. As a consequence, obtaining consensus on the "best statistical analysis" to use might not always be easy. The best statistical methods applied to unreliable data can only lead to unreliable results. It is therefore obvious that rigorous statistical methods should also be applied in data collection systems. This is particularly critical for fisheries data.

D. Practical guidance for research

94. The preceding discussions indicate that a major contribution of fishery science to the development of a precautionary approach to fishery management would be:

(i) To promote multidisciplinary research, including social and environmental sciences, because the availability of biological evidence has not prevented overfishing;

(ii) To expand the range of fishery models (bio-economic, multi-species and ecosystem models), taking into account environmental, species and technological interactions;

(iii) To analyse various possible management options using the whole range of available models, showing the likely direction and magnitude of the biological, social and economic consequences, the related levels of uncertainty and the potential costs (risk assessment). In situations of doubt and high risk of irreversible damage to the resource, scientists analysing options for management should systematically analyse and highlight the most pessimistic scenarios; 17/

(iv) To develop scientific guidelines and rules for multi-species and ecosystem management as a basis for agreement on acceptable degrees of disturbance. Because of the inherent uncertainty in research, conventional, quantitative reference points and thresholds will have to be agreed on; 18/

(v) To improve statistical methodologies for assessing the biological and economic parameters, testing their sensitivity to uncertainties in the data used and systematically estimating bias and precision in the derived parameters. The sensitivity of models to uncertainties in their parameters and functional structure should also be tested;

(vi) To improve understanding of environmental impact, raising the awareness of fishermen to the possible impact on fisheries potential resulting from fisheries as well as from environmental degradation caused by other industries. Environmental Impact Assessments should be used more frequently. Research is needed on better ways to use gear and also on the development of better gear with better selectivity and less long-term environmental impact.

Notes

1/ The inadequacy in management of straddling and highly migratory resources (and of many exclusive economic zone resources) results essentially from the common property nature of the resources and the lack of effective mechanisms to directly control fishing effort levels in the absence of an explicit agreement on the allocation of resources between users.

2/ For more detailed analysis on uncertainty and management reference points the reader is referred to the paper prepared by FAO for the present Conference on "Reference points for fisheries management: their potential application to straddling and highly migratory resources" (A/CONF.164/INF/9).

3/ This factor often leads to proposals to introduce a social discount rate. However, there are severe practical difficulties in determining such rates and implementing them. A more satisfactory solution would appear to be through proper pricing of resources, including not only the marginal cost of harvesting, but also the foregone value of catches no longer available to future generations.

4/ In a typical Mediterranean multi-species trawl fishery, where long-lived bottom species (e.g., seabream and red mullet) are targeted together with short-lived pelagics (e.g., sardine), this would imply fishing sardine well below the possible level of harvest in order to comply with the guidelines for seabream and mullet. The problem has been recognized in the report of the FAO Expert Consultation on Large-Scale Pelagic Driftnet Fishing (Rome, 1990).

5/ Surplus production models, on which the concept of MSY is based, assume that natural renewable resources are "sustainable" (i.e., able to regenerate themselves year after year) at various levels of abundance depending on the level of harvest. A stock can in theory reproduce itself, and be

considered sustainable, at high (virgin state), medium (MSY level) and even low levels of abundance, except for some species such as marine mammals and sharks. However, as stocks are fished down, their variability and the risk of collapse increases and it should be clear that all levels of theoretical "sustainability" are not equivalent in terms of risk for the resource.

6/ For instance, a "minimum biological acceptable limit" related to recruitment or reproductive biomass would be a threshold beyond which the recruitment has a given probability to decrease or when the residual spawning biomass (escapement) falls to, say, 20 per cent of the virgin spawning biomass. Pre-established measures triggered automatically at threshold levels would be particularly advisable in areas of high environmental variability (upwellings) or for species with particularly low resilience (e.g., small cetaceans, sharks, etc.).

7/ This concept of "compensation", which proposes that human activities should lead to "no net loss of habitat", implies that, if some part of a habitat must be damaged somewhere, compensation is provided somewhere else.

8/ Research has amply demonstrated during the last two decades that even at MSY, stock instability and risk of recruitment failure are sometimes already high. This, added to the fact that MSY and the fishing rate corresponding to it are usually difficult to determine accurately, should lead us to consider MSY as a non-precautionary target for stocks with low resilience or high natural variability.

9/ "Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable."

10/ One of these courses of action could be a moratorium, but if reference points are selected on a cautious basis and monitoring produces information on a quasi-real-time basis, a range of actions is available (seasonal or temporary closures, modification of fishing patterns, significant reduction of effort, etc.).

11/ A discussion on this issue can be found in: "Environmental capacity. An approach to marine pollution prevention", GESAMP Report and Studies, No. 30, 1986.

12/ The classification of a technology will depend on the type of habitat. Heavy trawls may be considered "green" on deep muddy grounds but "red" in shallow estuaries and coastal zones or coral reefs. Artificial reefs might be on a grey or orange list because their impact on coastal habitat is long lasting and, if made of derelict material, they may contaminate the environment.

13/ The successful efforts made by the Inter-American Tropical Tuna Commission in the Eastern Central Pacific area to train crews of the region in

effectively avoiding by-catches of dolphins through the use of appropriate technology is a good example of what can be achieved in this respect.

14/ An example can be found in the Code of Practice to Reduce the Risk of Adverse Effects Arising From Introduction and Transfers of Marine Species including the Release of Genetically Modified Organisms which has been adopted by the International Council for the Exploration of the Sea and the European Inland Fishery and Advisory Commission of FAO. The Code foresees that "Member countries contemplating any new introduction [of genetically modified organisms] should be requested to present to the Council, at an early stage, information on the species, stage in the life cycle, area of origin, proposed plan of introduction and objectives, with such information on its habitat, epifauna, associated organisms, potential competitors with species in the new environment, genetic implications, etc., as is available. The Council should then consider the possible outcome of the introduction, and offer advice on the acceptability of the choice."

15/ In exclusive economic zone fisheries, where effective effort controls have been established, there is often a requirement to obtain prior consent from the management authority before a new vessel is ordered or even before the banks are approached for a loan for this purpose.

16/ It should also be clear that in order to satisfy the requirement of the 1982 Convention for the best scientific evidence available, the information must be scientific (i.e., obtained and presented in an objective, verifiable and systematic manner) and it does need to be made "available" to all concerned. This, in the context of straddling and highly migratory resources, requires the existence of effective international scientific cooperation and the elimination of non-reporting and misreporting.

17/ Models which predict rapid collapse when effort develops beyond the MSY level (such as the Gulland-Schaefer production model or the Ricker stock-recruitment model) should be used rather than models assuming high resilience of stocks at high fishing rates (such as the Fox production model or the Beverton and Holt yield-per-recruit and stock-recruitment models).

18/ For instance, if it is agreed that it is safe to exploit a resource at two thirds of its MSY, it will be necessary to agree on the reference data set and on the conventional model on which to base the calculations because the true value of 2/3 MSY and of its corresponding level of effort will never be exactly known and may vary according to the model used.

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REFERENCE POINTS FOR FISHERIES MANAGEMENT: THEIR POTENTIAL APPLICATION TO STRADDLING AND HIGHLY MIGRATORY RESOURCES

Explanatory note

The United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, at its second session, held in New York from 12 to 30 July 1993, requested the Food and Agriculture Organization of the United Nations (FAO) to prepare an information paper on the concept of maximum sustainable yield (A/48/479, para. 17 (c)). Pursuant to that request FAO has provided the present information paper.

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I. SUMMARY

1. A wide range of reference points has been proposed in the literature on fisheries management, primarily for management of national fisheries. No methodologies have been explicitly developed for straddling stocks and few specifically take into account the special characteristics of highly migratory species. As a result the present paper has had to rely largely on management experience with national fisheries.

2. Since it is axiomatic that a resource can only be assessed and managed based on a knowledge of removals throughout its range, the issue for straddling and highly migratory stocks is more a practical than a theoretical problem. Clearly the data collection and analysis required for the assessment of straddling and highly migratory stocks presents more problems when uniform standards for the collection of data are not established, than for the data-dependent management methods used exclusively in the national fisheries of developed countries.

3. A wide range of new biological reference points has been proposed in recent years and these tend to focus on defining acceptable levels of fishing mortality and minimum spawning stock criteria rather than on catch and fishing effort criteria. This attention to minimum spawning biomass is beginning to suggest limits which should not be exceeded, rather than targets for fishing, and this change in emphasis is well adapted to precautionary or risk-averse management strategies.

4. Where new targets for fisheries management have been proposed, whether based on desirable catch and effort, desirable stock size or economic considerations, they have all recognized that the optimum fishing effort for sustainable exploitation is below, even significantly below, the level of effort corresponding to the maximum sustainable yield (MSY). The biological and economic gains from significantly restricting fishing effort more than offset the losses in yield from choosing more modest targets, which in the long run are minor.

5. The choice of maximum sustainable yield as the accepted reference point for fisheries management purposes was applicable when fisheries were in an expanding phase and this reference point was used as a rough production target. As fisheries have become increasingly over-exploited, MSY may still be a valid reference point, but only as representing an upper limit beyond which stocks become progressively over-exploited and a minimum requirement for effort reduction policies.

6. Most of the difficulties experienced with using any target reference point result from the considerable uncertainties as to the current position of the fishery in relation to it, given poor data and environmental variability. Few fisheries are stable because environmental changes influence stock size. This means that stable production levels are only possible with widely varying fishing rates from year to year.

7. One of the difficulties with using MSY as the main reference point as a target for management is that of determining where the point is and where a fishery is in relation to that point. This can usually only be determined after MSY has been reached, and even substantially passed, and the level of production is clearly diminishing. It is suggested that MSY can still be a useful reference point if it is used as a limit reference point instead of a target. Once a limit reference point is reached it would automatically trigger certain measures to curtail fishing in order to commence stock rebuilding.

8. Standard fishing effort and current mortality rates caused by fishing on stocks can only be roughly estimated for open-access fisheries where effort is difficult to adjust and misreporting or poor estimates of catch affect the accuracy to which a given fishing rate can be measured.

9. The present paper recognizes the high level of uncertainty in management advice for straddling and highly migratory stocks owing to poor statistics, as the most serious impediment to implementing low-risk exploitation strategies. Improving data gathering and analysis should allow management to use less restrictive precautionary reference points without a corresponding increase in the risk of over-exploitation.

10. For comparative evaluation, a summary of the main reference points considered in the present paper is contained in annex I, together with their respective data needs and advantages and disadvantages.

II. INTRODUCTION

11. Fisheries management is not synonymous with the attainment of a single reference point. This has already been recognized with the acceptance of the concept of optimum sustainable yield, as contained in the 1958 Geneva Convention on Fishing and Conservation of the Living Resources of the High Seas. The concept of optimum sustainable yield recognizes economic, social and biological values for the basis of fisheries management objectives. However, because of economic and social differences amongst fishing countries, optimum sustainable yield does not have a standard technical application and therefore cannot be considered a technical reference point. It does, however, remain a valid concept for fisheries management based on a mix of references as long as the fishery remains within a "safe area" as defined by technical reference points.

12. Marine fish populations are not visible for direct census and therefore assessments are made on the basis of conceptual models whose validity is often open to question, and changes with time. These models rely on estimates of biomass, catch and fishing effort, and mortality rates that all contain significant uncertainties and these affect estimates of stock size. Errors can occur in resource surveys, in the use of inappropriate models, misreporting or non-reporting of catches, as well as in estimates of the effective fishing effort exerted on the stock under "open access" conditions.

13. The basic premise for fisheries management follows that of animal husbandry, in aiming to provide a sufficient number of spawners (i.e., escapement) for new recruitment to a fishery. Beyond this requirement the stock

is surplus to conservation needs and can be taken (i.e., catch). In this way the prime consideration for fisheries is that of catch versus escapement. Catch has therefore to be controlled to ensure that sufficient escapement occurs to satisfy spawning requirements. The effectiveness of protecting spawners is measured by monitoring new year classes entering a population as well as monitoring the age structure of the population. Not all fishery models have the same data requirements or impose the same costs in data collection and analysis. Analytical models incorporate growth, mortality rates and information on fecundity, but they are used mostly in developed-country fisheries in high latitudes. Such data are not commonly available for many tropical species, which means that management for such fisheries, by referring to a single reference point, will be problematic and require precautionary approaches to avoid stock collapse.

14. The necessity of using analytical models for the assessment of fish stocks imposes data requirements that are demanding. The provision of proper systems for collecting, storing and analysing fishery information and conducting fishery surveys and research, are mandatory for determining whether management targets are being met and for evaluating the effectiveness and impact of a management regime. Further, it can be demonstrated that for a comparable level of risk of stock collapse, a fishery with poor research and management must be fished less intensively than if research and management are well developed.

15. All technical reference points require estimation of the relationship between fishing mortality and stock size (see annex I). Estimates of stock size and fishing effort are not always easily defined and can be modified by environmental conditions which can change a stock's availability to fishing, its vulnerability and hence the effective fishing power of a fleet.

16. In order to determine when an optimum has been reached there must be continuous statistical monitoring of the catch, the fishing effort and a range of biological and economic information. There must also be a realistic appreciation that the actual values used can only be known with questionable precision. It is also important not only to consider the effect of managing a fishery according to certain reference points but also to consider the potential consequences of applying wrong reference points under the conditions of uncertainty that always apply to the management of a fishery, or misinterpreting the position of the fishery in relation to a correct reference point.

17. The assessments of fish stocks presented to fishery management forums are characterized by the use of standard "accepted" procedures which, once adopted, are only changed when evidence of a clear improvement in methodology is generally accepted by all parties. In time, the methods used acquire a conventional character, which can disguise the level of uncertainty associated with population estimates for a fishery. Explicit estimates of accuracy or precision are rare in the stock assessment literature, and further attention to defining more precisely level of error and the associated risk of exceeding fishery management targets is required. Annex II illustrates three important points:

(a) It is clear that the current stock size and fishing mortality are known with relatively low accuracy in most fisheries. Although with a history

of past assessments the above estimates may improve, it should be recognized that even under optimal conditions fisheries management does not operate in a risk-free environment. Total yield may appear to be known with a higher precision than other variables, but often suffers from high or unknown biases as a result of discarding and misreporting, particularly if management is by catch quotas. Survey estimates of biomass typically have a higher variance but may be less biased, and have the potential to be improved with research investment. In all cases, the relative change in population size from year to year will be known with more precision than absolute values;

(b) Management targets with equal levels of risk will require lower levels of removals and more conservative reference points if statistical data are poor and non-reporting or misreporting is the case, than if proper attention is paid to data gathering;

(c) In order to reduce the risk of error in determining the present position of the fishery relative to the reference point, two or more different stock assessments, using independent data sets, will be necessary, but the exact status quo for the fishery is unlikely to be known with an accuracy of more than ± 10-30 per cent, even with a high expenditure on research.

18. This means that maximum sustainable yield (or any other reference point used as a target) will be exceeded at least 50 per cent of the time, and often by a considerable margin. In the case of MSY, this target reference point (TRP) has lost its reputability, primarily as a result of errors in population estimates, and the corresponding consequences to fisheries. Unknowingly overfishing this target in error is more serious and less easily reversible than underfishing it. Had full account been taken of errors in the population estimates, fishing effort would have been aimed at lower levels of exploitation. Based on this perception, and taking risk and uncertainty into account, the present paper suggests that target fishing rates should be set at levels of effort below that yielding MSY, with an explicit attempt made to assess the probability that a dangerously high fishing rate, or limit reference point (LRP), be only rarely exceeded.

19. The conclusion is therefore that insufficient attention has been given to "errors in estimates" and in view of the inherent uncertainty that exists in managing fisheries, no single target reference point can be relied on for the basic conservation of fisheries. A set of reference points or management criteria is required, with renewed national commitment by all parties fishing a highly migratory or straddling stock towards statistical gathering. This should focus proper attention on determining confidence intervals on data sources through standardization of data gathering and analysis procedures, cross-referencing and subsequent adjustments to management targets. The present paper provides comments on the usefulness of specific reference points, in particular their application either as target reference points, or as so-called limit reference points which automatically trigger pre-negotiated management responses.

III. REFERENCE POINTS: AN EVALUATION

20. A reference point is considered to be a conventional value derived from technical analysis which represents a state of a fishery or population, and is intended as a guide for fisheries management.

21. Traditionally, reference points have been considered desirable targets for management. It had been assumed that it is possible to "tune" a fishery such that one or more control variables, as determined from statistics, are (believed to be) close to a pre-established reference point. Such a target for management can be referred to as a target reference point (TRP), and MSY had classically been used in this sense.

22. Reference points are usually derived from a particular biometric or econometric mathematical model. The models underlying the MSY point were originally equilibrium models implying that the points on the curve represented the yield that would result from a given standard effort applied for the years necessary for equilibrium to be reached.

23. It is important to recognize that no TRP known to date is stable, whereby a fishery will gravitate to an equilibrium point automatically, or return to that point immediately if disturbed. TRP management, particularly if based on catch limitations or total allowable catches (TACs), requires active monitoring and continual readjustment of management measures on an annual time scale, because of the substantial uncertainty in the status of a fishery in relation to its reference point.

24. Management by reference point should recognize this inherent uncertainty in our knowledge of the status of the stock, and the fact that, ironically, our knowledge of the current status of the resource is poorer than our ability to reconstruct stock status in previous years. Such uncertainties will inevitably be greater for straddling and highly migratory resources, where multiple fisheries render common data gathering for the stock problematical.

25. It is incorrect to assume that a given level of fishing effort allows a surplus yield to be maintained indefinitely without regard to environmental conditions. Dramatic improvements in fishing technology have allowed fleet fishing power to be exerted rapidly and moved from one fishery to another in short time periods. The reference point MSY, which in the 1950s could take half a decade or more to reach, can now be achieved in the first year of a new fishery. Under circumstances of high initial catch rates, a wide overshoot of MSY is inevitable, resulting in associated ecological changes and serious economic problems in reducing fishing effort so as to adjust to a lower equilibrium MSY level in later years.

26. As a result, the use of production models, in particular those that assume equilibrium in forecasting short-term yield, has been criticized. Problems with making decisions under conditions of uncertainty with data, environmental conditions and spawning success have resulted in management of many fisheries relying on analytical models, whereby the catch data are supplemented with biological sampling and regular surveys of fish populations. The problem of high precision has, however, not been solved, and the techniques for

establishing whether a reference point is being met in a given year remain based on the validity of the population models used, and on our best estimates of the dynamics of a fishery. There is presented below an examination of reference points which are formulated mostly in terms of the role of fishing mortality (F) which these points are intended to achieve.

A. The maximum sustainable yield criterion: F_{MSY}

27. The 1982 United Nations Convention on the Law of the Sea specifies only one technical reference point (the maximum sustainable yield) as a descriptive term for the highest point of the curve traced between the annual standard fishing effort applied by all fleets and the yield that should result if that effort level were maintained until equilibrium is reached. This is at first sight an obvious target for management of a single-species fishery, and it was widely used for this purpose by fishery commissions in the 1960s and 70s. Subsequent developments in the theory and practical experience in fisheries management have cast doubts on MSY as a safe TRP.

28. MSY, and its equivalent levels of standard fishing effort/fishing mortality rate (f_{MSY}/F_{MSY}), was formulated first for the symmetrical Graham-Schaefer or logistic model (see annex III). The concept was model-based and required statistical fitting of historical catch and standard effort data. The effort level at which the f_{MSY} catch occurs can be converted to a fishing mortality F_{MSY} if the constant of proportionality, q, is known. Choosing F_{MSY}, or any other reference point, implies that the underlying mathematical model of fish population dynamics is (at least implicitly) agreed on in choosing this TRP. The question may however be less one of selecting a reference point with the most robust theoretical underpinnings, but one that provides conservative advice under conditions of uncertainty, and from this perspective the MSY level has not performed well.

29. Few explicit estimates have been possible of the accuracy with which MSY conditions have been reached, but inspection of many production models suggests that knowledge of the current death rate attributable to fishing (and hence the accuracy with which a given target for the fishing rate is attained) is hardly likely to be better than ± 20 per cent. The MSY is obtained by statistical fitting of historical data to the model, and this implies that what happened in the past has a similar probability of occurring in the future. However, this does not take into account variations and trends in environmental conditions or in ecosystem species composition under fishing pressure. In a series of years with very poor recruitment, a fishing mortality rate will produce a yield well below that predicted for the same level of effort from fitting the model to past data series. Attempting to harvest the statistically obtained MSY in these years of low stock size would require fishing above, and possibly well above, F_{MSY}. For this reason, the use of the term "sustainable" when speaking of a "maximum sustainable yield" obtained in the conventional way has been criticized.

30. Given the uncertainty as to the actual status quo with respect to this (or any other) reference point, a fishery believed to be operating in the region of F_{MSY}, in probability terms, is 50 per cent of the time either overfishing or underfishing with respect to this benchmark. The biological responses of the resource to overfishing or underfishing are not necessarily symmetrical: overfishing leads to fewer age groups in the fishery, hence increasing the contribution of occasional good year classes to the overall yield, as well as leading to declining mean sizes and catch rates and progressively increasing the return time to acceptably high stock sizes. Relatively constant year-to-year recruitment is the exception rather than the rule, but reduced or less regular recruitment with declining spawning stock size is accompanied by increased dependence for stock replenishment on newly maturing age classes. Increased variations in abundance as a result of a greater influence of environmental changes on the stock size lead to increasingly heavy reliance on research data, especially if catch quotas are the preferred management measure. From theoretical considerations, a management system that treats a stock assessment simply as providing a TRP, without recognizing statistical uncertainties in the fishery management process, will not be effective.

31. Model uncertainty is often a serious problem. The uncertainty as to which type of yield model is appropriate for a particular fishery can, unfortunately, only be resolved when overfishing has occurred and the total effort that provides MSY has been exceeded. Catches may then drop (implying a dome-shaped model) or reach a plateau (as is often the case in tropical shrimp fisheries), giving, finally, the clue to the appropriate type of model.

32. As a result of the uncontrolled fleet dynamics of fishing investment, effort overshoots of the f_{MSY} target are an almost inevitable feature of open-access fisheries, so that the type of model to use, and the level of effort or fishing mortality which approximately corresponds to MSY, may be only relatively well known, even in the best of circumstances. Controlled overfishing strategies have even been proposed as one way of more precisely locating MSY conditions. Such strategies are however dangerous and difficult to reverse: surplus fishing vessels, once established in a fishery, may be difficult to displace, with limited alternative income-earning opportunities, and a loss in economic yield will certainly occur. It is for this reason also, that other, more desirable and safer target fishing rates (such as two thirds of the effort providing MSY) have been difficult to agree upon.

33. The effects of heavy fishing in reducing stock size can lead to a species losing its competitive advantage as its ecological niche is occupied by other competitor species with similar food requirements, but not necessarily of the same economic value (e.g., skates instead of haddock; dogfish instead of cod). The probability that the ecosystem will move to an alternative ecological configuration seems to increase as effort arrives at MSY levels or beyond.

34. It has been pointed out that there is often an erroneous identification of MSY conditions for little-studied stocks with the maximum average yield (MAY). This latter measure has occasionally been used as a reference point, but gives dangerous weight to the early, more productive years of the fishery when the virgin stock was being fished down. A literal interpretation of MSY for a stock subject to wide variations in recruitment, would be that level of catch which

could be removed in perpetuity from the resource with a low probability of endangering it under conditions of environmental and recruitment variability, i.e., where the same yield could be safely removed in good or bad years. This interpretation of "MSY" is radically different, and requires a different notation from MSY as normally derived, and this reference point is referred to here as the maximum constant yield (MCY). This TRP implies much lower levels of fishing mortality than at MSY as defined conventionally. Such a new definition could, however, provide a useful target for stock rebuilding, and could be estimated from simulation if some information were available on the likely variance of annual recruitment.

35. Following the postulation of the marginal yield concept, fishing at the effort level that corresponded to two thirds of the effort needed to produce MSY would yield a very large fraction (possibly as high as 80 to 90 per cent) of the overall yield at MSY, with a reduced risk of stock collapse. This empirical measure, although safer than f_{MSY}, like $F_{0.1}$, has been criticized as empirical and insensitive to changes in recruitment. Such reference points derived from production models, such as MSY, suffer from difficulties of population analysis if the competing fleets exploiting a resource do not exploit the same age groups in the stock. Under these conditions some form of analytical approach is necessary. The first of these analytical reference points defined was F_{MAX}.

B. The maximum yield per recruit criterion: F_{MAX}

36. The theory of population dynamics placed early emphasis on the calculation of that level of fishing mortality for a given size at first capture, which maximizes the yield from a fixed number of recruits with fixed growth and natural mortality schedules entering a fishery. This was one of the earliest benchmarks for fisheries management, and as with MSY, suffered from a number of failures as a target for fishing, since it does not take into account the effect of fishing at F_{MAX} on the reproductive potential of the population. Although generalizing can be hazardous, there seems little doubt that this reference point usually corresponds to a higher fishing rate than F_{MSY}, and that fishing at this rate over a period of time is liable to deplete the spawning stock and reduce future recruitment. Although there seem to be good reasons for retiring F_{MAX} as a management target, it could be a possible upper limit or limit reference point (LRP).

C. The marginal yield criterion: $F_{0.1}$

37. $F_{0.1}$ is the fishing mortality rate at which the slope of the yield per recruit curve as a function of fishing mortality is 10 per cent of its value at the origin (see annex IV). For a number of species there is no clear maximum to the yield curve per recruit, but unlike F_{MAX}, the $F_{0.1}$ point does not require this, since it is an arbitrary criterion based on the initial slope of the yield per recruit curve.

38. The $F_{0.1}$ measure, although arbitrary, is in a sense a bioeconomic criterion, in that a marginal yield of less than 10 per cent was felt to be the point at which most fisheries administrators would consider further increases in fishing

mortality or effort to be no longer economically worthwhile. This measure has been widely used in many fisheries of the North-west Atlantic. F-based strategies have been followed off the coast of eastern Canada for more than a decade, and $F_{0.1}$ is often used in establishing overall quotas. Declaration of the correct and unbiased catch data is essential to estimating current F-values under quota control, but there has been a gradual erosion of the accuracy of commercial catch reporting. This has affected scientific assessments, especially where fleet overcapacity is a problem. As a result there has been a high probability that target F-values are exceeded. This, and not just the changes in $F_{0.1}$ that occur with changing fishing patterns and input values for M (natural mortality rate: see below), may be the main explanation for declines in several stocks managed under $F_{0.1}$ criteria.

39. A more serious problem in using this TRP for straddling, and even more so for highly migratory stocks is how to calculate a value for $F_{0.1}$, if fleet-specific vectors of fishing mortality-at-age for an exploited resource are quite different within different jurisdictions, and the relative fishing effort levels in each jurisdiction change from year to year.

D. Reference points based on the natural mortality rate: M

40. New fisheries usually develop in the absence of adequate assessment information, and management has to proceed on the basis of information available at the time. It is important for the rate of increase in fishing during the early stages not to exceed the rate at which the capacity of the resource to support fishing is known. A more cautious approach may result in underexploitation, but this will not necessarily lead to a long-term loss of potential yield. In the 1960s and 1970s, many new fisheries developed for which the only data on stock status was one or several estimates of biomass from exploratory fishing or fishery surveys. In an attempt to provide some basis for fleet and fishery development, a simple empirical formula for MSY was proposed in terms of the virgin biomass B_0 and the natural mortality rate, M: notably, MSY is equal to half of the natural mortality rate times the virgin biomass ($MSY = 0.5MB_0$). This follows the symmetrical Schaefer yield model in assuming that MSY will occur at half the virgin stock size B_0, and that at MSY, the fishing mortality and natural mortality rates will be equal, so that if M is known, a target fishing rate at the same level could be defined such that deaths attributable to fishing equal those attributable to natural causes. Subsequently, a more cautious approach was recommended in which death rates attributable to fishing were maintained below those attributable to natural causes (predators, etc.).

E. The overall mortality rate at maximum biological production: Z_{MBP}

41. Production model theory begins with the idea that virgin populations are dominated by large, older individuals, whose contribution to biological production (growth, yield plus deaths attributable to predation) is lower than when younger individuals dominate the population. The existence of a mortality level Z_{MBP} can be postulated at which the biological production from the stock is

maximal, and this is shown for the Schaefer model in annex V. This raises the general observation that the causes of death of fish in the wild are rarely accurately known, so it might be better to use as an overall reference point the overall mortality rate Z experienced by the stock due to all causes of death.

F. Target reference points derived from stock-recruitment considerations

42. As a result of heavy fishing and depressed stocks, fishery scientists in the North or North-east Atlantic have moved in recent years towards emphasizing spawning stock considerations when offering advice to management bodies. This has been phrased in terms of spawning stock biomass or biomass per recruit ratios, and refers to the reproductive potential under virgin stock conditions. This has led to increased research in recent years on the density-dependent processes that underlie fishery dynamics. These density-dependent processes have revealed that the number of recruits increases as adult populations grow from very small sizes, but for many resources the number drops at a high adult population size, owing to individual competition for food, space and spawning sites.

43. Simulations have shown that for northern demersal stocks a yield of at least 75 per cent of MSY is possible as long as the spawning biomass is maintained anywhere in the range 20 to 60 per cent of the unfished level, irrespective of the spawner/recruit relationship. For north-temperate groundfish stocks, a relative spawning biomass in this range can be achieved by choosing an effort level that will reduce spawning biomass per recruit to about 35 per cent of the unfished level. The equivalent reference point is usually very close to $F_{0.1}$. The relationship between spawning stock size and number of recruits is of key importance to the decisions made with regard to reference points, but a long time span of annual data on adult population size and recruitment under a wide range of population sizes is needed to produce a reliable stock/recruit curve (see below). This is rarely available for setting reference points for less frequently studied stocks.

44. The use of reproduction-based TRPs has been pioneered in the International Council for the Exploration of the Sea (ICES) area, based on plots of recruitment on spawning stock biomass. Three arbitrary criteria have been proposed, one of which, FMED, has the characteristics of a TRP and corresponds to the fishing mortality when increases in stock size attributable to recruitment in half of the years have more than balanced losses attributable to mortality. Two other benchmarks (F_{LOW} and F_{HIGH}) surround F_{MED}, and are similarly defined to result in recruitment exceeding removals in 90 per cent and 10 per cent of years, as represented by the proportion of data points for recruitment above the line through the origin corresponding to that level of fishing mortality (see annex VI), and have the following properties:

F_{LOW} a low probability of stock decline, and some likelihood of stock increase;

F_{MED} likely that current stock levels will be sustained;

F_{HIGH} likely that fishing at this level will result in stock declines.

All of these measures appear less susceptible to assuming an incorrect value of the natural mortality rate than F_{MAX} and $F_{0.1}$ levels. Although F_{MED} is the fishing mortality rate at which, on average, each year class replaces the spawning biomass of its parents so that the population fluctuates without trend, it should be noted that this measure, which is independent of the form of the stock recruitment relationship, fell close to F_{MAX} and F_{MSY} for Georges Bank haddock.

45. Calculations of the spawning stock biomass per recruit (SSB/R) can be carried out in a manner similar to that for yield/recruit calculations if information on maturity/fecundity at size or age is available, even if the stock-recruit relationship is unknown. These calculations are usually expressed as a percentage of the SSB/R under unfished conditions (per cent SSS/R). In a recent comparative study, per cent SSB/R was found to be positively correlated with natural mortality and negatively correlated with various indexes of size: thus cod and most flatfish support low levels of per cent SSB/R, but some pelagics require values as high as 40 to 60 per cent for consistent stock replacement. Although these conclusions agree with those in the section on reference points above, it is probably dangerous to extrapolate them widely outside their region of origin, since the detailed data sets this generalization is based upon are mainly restricted to demersal fishery resources in higher latitudes. None the less, the use of per cent SSB/R criteria is not as information-demanding as other reproductive criteria, and has potential in the present context.

G. Target reference points derived from economic considerations - the optimal fishing effort: f_{MEY}

46. The normal workings of the market are believed to maximize economic benefits to participants, but in open-access ocean fisheries the institutional framework does not ensure that the individual efforts of fishermen, working to improve their individual economic situation, will guide the net sum of private activities towards the common good. In fact, recent FAO analyses of global fishery trends have revealed a general state of overexploitation of many world fishery resources, and that the high level of over-investment in fleets is the major causal factor for overfishing within and outside exclusive economic zones. Combined with restrictions on fisheries within exclusive economic zones, this has been a motive force for movement into largely unrestricted fisheries beyond 200 miles.

47. An extensive literature on fisheries economic theory has developed in which the Gordon-Schaefer equilibrium production model plays a central role. This theory is summarized briefly in annex III, which shows that theoretically there is at least one economic target for exploitation, the effort level yielding the greatest rent from the resource, and that for a linear cost curve, this is realized at a lower level of overall fishing effort than MSY. The optimal effort level, however, is responsive to changes in the economic environment, such as the market price of fish, interest rates and the costs of fishing, and is not independent of changes in fish abundance.

48. Although economic considerations obviously should play an overriding role in national decisions to participate in a fishery, perhaps one further reason why such economic reference points may not be practical for the management of straddling stocks (and even less so for highly migratory resources) is that each national fleet may have a different economic optimum, depending on its costs, earnings and national market prices. In practice, F_{MEY} is not easily defined in most fisheries involving fleet components with different gears and fishing practices. Most fishery administrations pay little attention to the size or composition of fleets and few actively monitor fishing equivalencies between different fishing vessels or gears. Not surprisingly, fleets experience economic difficulties either from declining catch rates per vessel even if overall declines in total catches are offset by price increases, or from increases in costs of a number of important inputs. Because of the socio-economic impact of a reduction in fleet operations, Governments often resort to subsidies to alleviate such impacts. This of course increases the structural difficulty associated with reducing fleet size/fishing effort and fish mortality, etc.

49. Although distance- and labour-related costs and market prices differ between countries fishing the same straddling stock, a criterion for an economic reference point should ideally eliminate fleet and industry subsidies, grants, loans, etc., since these payments distort operations. The extraction of resource yields, even if not at a maximum, would help to ensure against the negative effects of economic distortion. There can be little justification for continued unprofitable fleet operation if this destroys or prevents stock recovery.

50. MEY cannot be usefully considered as a TRP as long as the condition of free and open access prevails. Fishing effort will continue to expand past MEY to the point at which total revenues equal total costs and this point will also be to the right of MSY on the fishing effort axis, and likely to result in government interventions to alleviate economic hardships to fishermen and the industry when catches/profits decline.

IV. LIMIT REFERENCE POINTS FOR FISHERY MANAGEMENT

A. F_{MSY} as a limit reference point

51. Annex VII shows that using an LRP rather than a TRP could provide flexibility in choosing a more cautious F-based TRP that may be useful for management purposes. The approach is illustrated in the case of F_{MSY}, and considers three aspects that are each related to:

(a) The variability of the current fishing mortality (F_{NOW});

(b) The risk level that management may wish to take so that F_{MSY} may not be exceeded;

(c) A knowledge of the F_{MSY} which is accepted as the LRP.

52. The value for current fishing mortality rate F_{NOW} is usually the best estimate resulting from the analysis of statistical information and surveys, and its variability can be specified either in absolute terms (as a standard deviation) or as a fraction of the best available estimate of F_{NOW} itself. The approach suggested in annex VII is to establish a cautious F-based target for management such that despite uncertainty as to the exact current rate of fishing, this should not exceed some higher LRP (in this case F_{MSY}), more than an acceptable proportion of the time.

53. For example, the table in annex VII illustrates that with an acceptable 20 per cent risk of overshooting F_{MSY}, and a best estimate of current fishing mortality known to an accuracy of ± 50 per cent, the corresponding "safe" F-based TRP should be set at a fishing rate of F_{NOW}=0.42. That is to say, if F_{MSY}=0.6 is set as an upper limit to fishing mortality, then to be certain that this limit is not exceeded more than 20 per cent of the time, the fishing mortality rate to be aimed at should be F_{NOW}=0.42 instead of 0.6. These calculations illustrate the importance of sufficient and accurate information on the status of the fishery in developing risk-averse management strategies.

54. A more elaborate use of MSY as a limit for exploitation was incorporated in the new management procedure developed by the International Whaling Commission, where a maximum harvest of 90 per cent of MSY (set at 60 per cent of the unexploited stock level) is agreed upon. The overall catch is reduced progressively by 10 per cent for each 1 per cent shortfall of the stock below the MSY level, leading to a threshold for entry of the stock to a fully protected category, as soon as stock size drops to 90 per cent of the MSY level. This example also illustrates one other essential feature of an LRP-based management system: the pre-negotiation of future automatic management responses once the system enters a pre-agreed endangered state.

B. Limit reference points derived from stock recruitment considerations

55. Scientific attention has focused recently on the definition of LRPs which signal a dangerous situation of reduced probability of future recruitment to the fishery. Practical management advice has been recommended on the basis of a safe minimum spawning stock size, or on an F-level that provides what is believed to be a safe limit for spawning stock biomass/recruit (SSB/R), expressed as a percentage of the spawning stock biomass calculated for the virgin stock. Thus it has been suggested that to fish at some fixed rate is safe for demersal fish stocks so long as the spawning biomass remains above a pre-defined threshold size, but to suspend fishing when stocks drop below this level. Specific criteria that fall in this category, as mentioned, would be the F_{HIGH} used in the ICES area, since above this point there is little evidence that the stock can produce enough recruits to sustain itself. In the ICES area the stock biomass below which the probability of a poor recruitment increases as spawning stock decreases is referred to as the minimum biologically acceptable level (MBAL), and is intended for use as an LRP.

56. In the United States of America, fisheries are managed through management plans which require operational definitions of overfishing based on a maximum

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fishing mortality rate, minimum stock biomass or other appropriate biological reference points. Sixty per cent of these definitions to date have been based on spawning stock biomass per recruit analysis, with typical values ranging from 20 to 35 per cent of virgin stock levels. A survey of 91 spawner recruit data sets for Europe and North America suggests that the replacement per cent SSB/R (i.e., the fishing strategy which, on average, replaces the spawning stock) varies considerably between taxonomic groups, but averages 20 per cent overall. Given the relative depletion of many of these stocks, it is possible that these levels should be regarded as limits to exploitation rather than targets.

C. Limit reference points as "sets of rules"

57. LRPs can be incorporated into a set of management criteria, which if one or more are infringed, triggers a pre-set management response. One such set of constraints has apparently been developed for the Eastern Bering Sea/Gulf of Alaska groundfish fishery and includes (a) a threshold biomass set at 20 per cent of the virgin stock biomass, (b) a maximum fishing mortality rate set at 30 per cent of the relative spawning stock biomass per recruit and (c) a maximum fishing mortality rate set at 80 per cent of the natural mortality rate (M) for the species concerned; other possible warning signals suggested elsewhere are: (d) when total mortality Z rises above that corresponding to the maximum biological production from the stock, (e) when the mean size caught falls below the mean size at first maturity, (f) when the proportion of mature individuals in the stock falls, below some agreed percentage of that for the virgin stock and (g) when annual recruitment remains poor for a predetermined number of years in a row. Other robust indices which are often associated with low stock size, and hence reduced intra-specific competition, are increases in weight-at-age and reduced size at maturity.

58. For short-lived species (e.g., some squid resources), sets of rules may be invoked in sequence in the same season. Thus, fleet size and overall effort can be controlled to aim for a target level of escapement to spawning as an agreed percentage of that calculated for the same number of recruits with no fishing. This level can be fine-tuned during the season if a real-time measure of accumulated catches is maintained, and when ongoing surveys of abundance/availability allow real-time changes in the abundance of pre-spawning individuals to be monitored.

D. Limit reference points derived from economic considerations

59. It is generally acknowledged that one limit reference point on the curve of total revenue plotted against fishing effort, although extremely undesirable, is the point of bionomic equilibrium at which total earnings from the fishery equals the total costs of fishing. Although beyond this point the fishery is operating at a loss, the effort level corresponding to this point (point E in annex III), can in fact be exceeded, especially when subsidies distort the real cost of fishing. Since the catch rate is often assumed proportional to biomass, the catch rate or catch per unit of effort per standard fishing day is one LRP criterion employed, particularly in some fisheries for highly migratory resources where survey methods are difficult to implement. A useful economic

LRP is the minimum catch rate which yields daily earnings per cost of fishing at which the fleet extracts zero resource rent. It is presumably axiomatic that a fishing operation that generates zero or negative resource rent, but contributes to dangerously depleting the stock is difficult to justify. A possible economic measure that might be applied by participating countries in a fishery on straddling or highly migratory stocks would be to require participants to demonstrate that resource rent is being extracted from their fishing vessels.

E. Reference points based on measures of the size at capture

60. In assessing the effects of size at first capture on the yield per recruit from a stock, an optimum size at first capture that provides the maximum yield per recruit can be calculated for a given set of population parameters and a particular level of fishing mortality. In the case of straddling stocks and highly migratory species, however, it is not always possible for this optimal size at first capture to be maintained throughout the range of the unit stock, since different age groups may have different distributions or availabilities within the jurisdictions in which the stock may range. Maintaining a single optimal size at first capture would only be possible if arrangements were made for all harvesting to be carried out in seasons and jurisdictions in which the optimal sizes were available.

61. The problem of controlling overexploitation is, of course, most pronounced when the age at first capture falls below the average age at first maturity and there is a high risk of recruitment overfishing. If control of fishing effort is unreliable, one reference point would be to require fishing only to take individuals at a size at and above that at first maturity without discarding and inflicting damage to undersized individuals. There may be an advantage in cases where the natural mortality rate is not precisely known for basing biological reference points on the overall mortality Z experienced by the stock. A more practical biological criterion has been proposed, i.e., to limit the overall mortality rate to Z^*, the level at which the mean size in the catch equals the mean size at first maturity. Evidently the use of this type of reference points requires attention to the selectivity of the gears in operation.

V. SPECIAL CONSIDERATIONS

A. Reference points for highly migratory resources

62. The reference points mentioned above for the management of single stocks have different degrees of applicability for highly migratory resources, although the specific life-history characteristics of these resources argue more strongly against exclusive reliance on dynamic pool models as a sufficient response to the needs of management and conservation. Sophisticated management arrangements may be needed to deal with sequential fisheries. Although occurring to a lesser extent for some straddling stocks, it is typical of highly migratory resources that multiple fisheries occur at different loci on the overall migratory route. Such local fisheries are often seasonal, and often too short to allow declines in catch rate with time and size to be unambiguously attributed to fishing as opposed to migration. Each fishery may exhibit different availabilities to

fishing and different age compositions of the catch. Under these circumstances, no ready alternatives seem available other than pooling catch data and performing a global assessment, and then, where possible, moving to define a more detailed escapement or gauntlet model.

63. One practical consideration that applies to multi-jurisdictional fisheries for a common stock is that each fishing location may be assessed as favourable or unfavourable in relation to a size-based reference point, the optimal size at first capture, as judged from yield per recruit or spawner per recruit analyses for the whole life history. The sacrifices needed either to achieve an optimal yield per recruit or to protect the spawning stock or juveniles from overfishing are not equal for all participants and often depend on the actions of one or a few coastal States where these critical life history stages are undergone. Under these circumstances, it has been noted that the overall yield from the population if all parties are obliged to harvest the stock exclusively within their areas of jurisdiction will be sub-optimal if only a few (e.g., juvenile) age classes are available in a given exclusive economic zone. The optimal solution from a yield-per-recruit perspective would then be to seek agreement to ban all harvesting except in seasons/areas where the size frequency, catch rates and international market prices are optimal but, of course, to provide a catch quota or other compensation to those parties prepared to renounce the fishing of sub-optimal sizes within their own jurisdiction.

64. The best overall reference point is one ensuring that a certain spawning biomass survives all fisheries to reproduce the stock. It is clear that this can be achieved in a variety of ways, all of which all result in the same agreed cumulative risk of death prior to spawning. If for highly migratory stocks the mechanism proposed in the preceding paragraph is rejected in favour of sub-optimal harvesting within each jurisdiction, the vector of mortalities-at-age, and the allocations to which they correspond, can be decided by negotiation between participants.

B. Ecosystem considerations and reference points for multi-species fisheries

65. The 1982 Law of the Sea Convention pays attention to the potential impact that fishing one resource may have on others and on the food web as a whole. These kinds of impacts are likely to be most pronounced for species that are competitors, predators or prey of the target species, or are taken as by-catch. A set of species-specific reference points that explicitly recognizes all of these specific types of interactions and quantifies them has not been applied and goes beyond the level of knowledge presently available for almost all marine ecosystems. A notable attempt to do this is found in the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) but many Antarctic fin-fish resources, despite the clauses in the Convention, are severely depleted. To a significant extent this is not the result of a lack of reference points, but rather to a lack of control of access and means to enforce it. A further comment is that the Convention seems to assume that fishing rather than natural variation is the key causal factor in declines in stock size (if not, it will be impossible to prevent a decrease in the size of a stock to below that

which ensures stable recruitment). In reality, stable recruitment cannot be ensured by management action, even if stock sizes above MBAL are maintained.

66. Article II (3) (c) of CCAMLR explicitly requires a management response to potentially irreversible changes to the marine ecosystem as a whole owing to a wide range of possible causal factors. This risks leading discussion on appropriate action into a debate on what actions are irreversible, when an irreversible change has occurred, what elements of the ecosystem are controllable and to what extent. The above doubts also apply to the suggestion that resources of a marine area should be managed under large marine ecosystem principles, by species assemblages, or even more ambitiously, by multi-species virtual population analysis. The latter theoretically allows the trade-offs between human and fish predators of different ecosystem components to become more explicit but is extremely data-intensive, and at this point is merely of theoretical interest in relation to most resources of the type considered in the present paper.

67. From a practical management perspective, there is relatively limited experience with management systems deliberately manipulating the relative biomass of ecosystem components, and this approach requires a prior decision about what the relative abundance of the different species in a given ecosystem should be: noting that this may differ considerably from virgin stock conditions without necessarily compromising the survival of any of the species involved. Such changes affect the equity of fleets fishing different resources and requires negotiation between users of different components of the food web prior to selecting species-specific reference points for the ecosystem component in question. An example of an unresolved contention of this type is the tuna purse seine/dolphin interaction in the East-Central Pacific where there is disagreement between the users of these interacting resources on the effects of the overall tuna harvest rate and exploitation strategy on both resources. As an example of the complexities of species interactions which may nullify comprehensive multi-species approaches, it should be noted that at a high prey biomass (e.g., of a small pelagic fish, the sprat), cod food requirements may be provided for, but large sprat stocks prey on cod eggs potentially affecting cod recruitment.

68. In mixed-species fisheries such as most trawl fisheries, attempts have been made to manage a complex of stocks exploited by trawlers using separate trip limits or reference points by species, or two-tiered quota systems as used by the former International Commission for North-west Atlantic Fisheries, where the total allowable catch (TAC) for all species is less than the sum of TACs for individual species. Both of these approaches have usually led to high discards of unwanted species.

69. Adjusting the exploitation rate in terms of the natural mortality rate may be an empirical approach that could lead to a set of values for species F that are relatively invariant. This is more desirable than making F a function of current species abundance, which with variable environmental conditions would make the fishing mortality TRP a rapidly varying function of environmental conditions. Scaling the species-specific values of F-based LRPs for different food web components according to their relative rates of natural mortality remains a theoretical possibility, but one that seems difficult to implement for

fishing gear such as bottom trawls that are relatively unselective by species. For such unselective types of gears, a precautionary approach, aiming at very little or no risk at all for all species being exploited, would imply that the ecosystem exploitation regime is defined in terms of the species with the least resistance to harvesting, leading to gross underexploitation of the system and possibly foregoing important development opportunities; this suggests that developing more selective modes of harvesting is a high priority.

VI. SETTING MANAGEMENT OBJECTIVES

A. Multiple options for fisheries management

70. Prior to deciding upon one or several of the reference points summarized in annex I, the management objectives for a fishery must be agreed upon. For the stock component within exclusive economic zones, objectives may be decided upon from a mixture of social, economic or biological criteria. For distant-water fisheries, although economic criteria are important, they are not necessarily the same as for the coastal State, and there may be other criteria based on food security or access that are not exclusively economic. This contrast of objectives has already been evident within the Northwest Atlantic Fisheries Organization. Nevertheless, agreement on the appropriate technically defined reference point is the basis for a common approach to the management of straddling or highly migratory resources. By introducing limit reference points for triggering automatic management responses, agreement may be facilitated. In general, the optima for each objective will differ (see annex VIII), and parties will have to arrive at a compromise which takes into account, to the extent possible, the requirements of all sectors having an interest in the marine environment and its resources.

71. Most of the economic activities mentioned in annex VIII can coexist at medium to high biomass levels, but not at low biomasses. The problem in carrying out all of these strategies, is that many resources require a period of rebuilding in order for lost options requiring medium-to-high biomass levels to be recovered. For those few resources which still fall in the category of underexploited stocks, precautionary or probing strategies are suggested, which restrict fisheries to fishing intensities well below the likely MSY levels revealed by exploratory fishing.

B. Components of a reference point-based management system

72. The setting of management objectives for a new fishery and the actions they lead to should perhaps follow, with some variations, the following sequence:

(1) Exploratory fishing and research;

(2) Assessment of the state-of-living marine resources;

(3) Formulation of long-term management objectives and related reference points;

(4) Negotiation of effort or catch allocations by countries and fleets;

(5) Framing of an international management agreement and its approval by Governments;

(6) Translation of international agreements into fisheries laws and regulations;

(7) International or coordinated national provisions for control and surveillance of all participants;

(8) Provision for the routine collection of statistics and samples;

(9) Setting of annual targets for the fishery, where applicable;

(10) Monitoring of the stock, the fishery and the enforcement of fisheries law regulations;

(11) Review of objectives, research results, assessments and control measures.

73. Some items in this sequence (e.g., 3, 4 and 5), although they should be kept under regular review, will be difficult to achieve, and renegotiations to revise them may be difficult. Other items (e.g., 6, 7 and 8) will need to be reviewed at intervals of several years as conditions in the fishery change, and items 1, 2, 9, 10 and 11 will need to be reviewed annually if the optimal benefit from a resource is to be realized and the probabilities of overshooting the chosen TRP, or entering a dangerous zone, as indicated by an LRP, are to be minimized.

74. It will rarely be the case in the late twentieth century that a new fishery will arise that does not affect existing marine harvests, and where sequence 1 to 11 above can be redefined uninfluenced by an existing harvest regime for this or an associated resource. New fishery objectives in a region are almost always superimposed on or replace old ones, and often follow from the use of a new technology or the need to satisfy a new market demand, so that there will be a need to regularly revise the objectives of the fishery. Among the reasons for modifying the regulatory framework, which is growing in importance, are non-harvest uses of the resource, as a result of the interests of constituencies outside the fishery sector. There is thus a considerable danger that for multi-user resources there will be frequent changes in objectives. This can lead to time-consuming negotiations with a consequent danger of overexploitation as a result of disagreement between the parties concerned.

75. In the absence of a speedy negotiated settlement for a new reference point and associated management regime, a safe pre-emptive settlement should be arrived at following a precautionary approach. Given the problems involved in a group of States arriving at a system such as (1) to (11) above, there should be a strong bias in favour of continuity and conservation, and the avoidance, where possible, of new objectives and untested new technologies.

C. The role of scientific advice in defining reference points for management

76. Traditionally, the assessment and management of fish stocks has been a two-tier process: scientists present assessments in the form of one or more catch or fishing mortality levels aimed at maintaining or rebuilding stocks, and the managers make decisions on the level of harvesting to be followed. While fishery scientists may be the most highly qualified to assess the risk involved in any recommendation they present to management, they are aware that considerations of an economic and political nature influence the level of exploitation chosen by the fishery managers. In some fishery management forums fishery scientists have seen that the presentation of a range of possible quota levels results in the selection of one towards the upper level of the range of values decided upon. This type of consideration, and the high degree of uncertainty inherent in the assessment process, has often led to scientific advice being presented to decision makers not in terms of the uncertainty of the estimates concerned, but as one, or several, explicit levels of fishing mortality or annual catch, each referring to one of a number of alternative management strategies.

D. Stock-rebuilding strategies

77. Stock rebuilding is not achieved in a single year and F-based reference points corresponding to lower fishing rates need to be assigned some years in advance; one weakness of most current management systems is their heavy dependence on short-term decision-making. Nevertheless, the benefits of losing immediate gains while returning to safer biomass levels do merit examination. For example, for relatively long-lived species such as cod and haddock, it has been shown that rebuilding over moderate time spans (for example five years) is less economically destructive than short, sharp reductions in fishing mortality (two-year rebuilding plans), while longer rebuilding periods are likely to be too long to afford visible signs of effective recovery. In the case of short-lived stocks, the rebuilding time is likely to be correspondingly shorter. For many stocks which are currently heavily exploited, larger-than-normal cohorts make up a progressively larger part of the annual yield, but may not occur very frequently. Focusing on the protection of these larger-than-normal cohorts may offer the most rapid approach to rebuilding a stock.

E. Risk analysis and the use of reference points for managing resources in a fluctuating environment

1. Risks of over-harvesting and under-harvesting

78. Over-harvesting may lead to stock decline or collapse. If the conditions for safe harvesting can only be met by research, management and enforcement that exceed the resource rents likely to be generated by the resource, serious consideration should be given to reconsidering the desirability of sustained harvesting. Under these circumstances, when biomass is well above safe limits, intermittent harvesting or culling under close supervision may be a less costly alternative than trying to maintain a low but constant rate of harvesting.

79. The risks of under-harvesting are usually defined in terms of the short-term reduction or interruption of a steady flow of benefits to participants in the fishery and consumers, even though this may result in a net gain in the long term. One factor opposing such a risk, for participants, may be the rise in market prices resulting from a reduction in supply. Biologically, for species with low natural mortality, yield foregone should be largely available the following year, when the survivors in the unharvested biomass will have increased in individual size, and may have contributed to the recruitment of the stock. Even for species with high natural mortality, the unharvested biomass will make a contribution through predation to other, possibly commercially valuable, components of the food web.

2. Risks attributable to environmental fluctuations

80. The routine application of reference points in fisheries management would be greatly simplified if environmental conditions remained constant, but most fish populations show wide variations in annual recruitment, which follow a negative binomial or similar clumped distribution, with a large proportion of the exploited yield coming from a relatively small proportion of year classes. There is evidence that the chance of one or two very good year classes being succeeded by a string of poor ones becomes more pronounced as the exploitation rate increases, and this is the environment under which it will be necessary to test the performance of the different reference points.

3. Risks attributable to using the incorrect model

81. Four main uncertainties in simulating a fishery have been identified. These are: (a) measured uncertainty in inputs to the model (e.g., catches); (b) perceived uncertainty in inputs and uncertainty owing to data-dependent decisions during the analysis; and (c) model uncertainty. Testing a reference point using Monte Carlo simulations of a fishery is becoming more common. Such simulations can also be used to estimate the risks and costs of the management measures proposed, as long as all relevant factors are included in the simulation. In these modelling exercises there is always, of course, a danger that the wrong model will be imposed on the raw data.

F. Risk and precautionary approaches

82. A management framework that invokes pre-set actions once one or more reference points indicate that overexploitation is occurring is in effect a precautionary approach. One context for using this approach has been suggested by analogy to a thermostat: the fishery operating under strict access control, even if not subject to a catch target or limitation, once one or more LRPs or rules show evidence of overexploitation or illegal fishing, triggers a pre-established management action which reduces the fleet effort. This is maintained or reinforced until the resource shows signs of recovery, as judged by the same criteria. The effort control may be relaxed somewhat once the fishery is distant from all LRPs.

G. The uses of reference points with different management strategies

83. A frequent observation of fishery scientists is that although there are a number of useful and safe reference points for management, the design of the management regimes which use them is rarely optimal. Such regimes must include a decision-making forum to set guidelines, but the routine management and control and surveillance capability as well as the statistical sampling needed to generate objective ongoing information on stock status must operate largely autonomously once reference points, sets of rules and consultative and management procedures have been established. In this connection, the lack of definition of interactions between the successive stages in the management process is a serious source of uncertainty which can adversely affect the success of management, as can the use of exclusively short time horizons for determining harvesting strategy.

84. Shall there be open-access regimes or control of fishing? Many recent studies have emphasised that the open-access nature of most marine fisheries has been the principal cause of stock depletion, loss of biodiversity and of potential economic earnings, and of adverse impacts on fishermen's communities. Three types of management measure may be envisaged which control the effort exerted on the stock: (a) input controls, such as vessel and gear limitations in size and fishing power, restrictions on credit, limited licence or limited-access schemes; (b) output controls, such as restrictions on the total amount of fish harvested annually by the whole fleet (TACs), by individual vessels (individual quota schemes), or by taxes on landings. Such individual quota schemes are often made transferable through the creation of a market for access rights which, as in the case of landing taxes, may be employed by the management authority to extract revenue from the fishery.

1. Management using catch quotas as target reference points

85. It has been shown that for stocks with wide fluctuations in abundance (as for many pelagic resources), a constant catch quota corresponds to constantly varying rates of exploitation, and unless it is set at a low level, a significant probability of overexploitation always exists. Quotas tend to lag behind by one or several years the actual variations in recruitment, and particularly as good year classes are approaching full exploitation. A quota that would have corresponded to $F_{0.1}$ or even lower levels when the peak year class was entering the fishery now corresponds to f_{MSY} or even higher levels, and there is marked reluctance by industry to accept a sudden drop in supply under these circumstances. In the North Atlantic, management to date has been largely based on TACs, but there is growing evidence that advice on desirable catch levels has become less reliable as a result of unrecorded catches and high discards. The TAC recommended by scientists, that finally agreed to after political decision-making and the actual catches taken, have tended to increase in sequence.

86. If information is scarce or uncertain, then one of the few feasible quota options may be a very low, fixed quota, using TRP criteria developed to ensure a

pre-set probability of F_{MSY} being exceeded, or with TRP criteria such as F_{MSY}. This approach could be adapted to straddling-stock management, with a cutoff point dictated by one or a series of LRPs which measure when stock size is critical, and the fishery should then be temporarily interrupted until unambiguous signs of recovery are seen.

87. One of the mandatory requirements for quota management under open access, even at apparently reasonable F levels such as $F_{0.1}$, is the need to ensure accurate, real-time estimates of catch, age composition and standardized fishing effort. The fact that many conservatively targeted quota management systems have failed, even for proprietary resources of exclusive economic zones, should prompt a re-examination of all facets of the management procedure. The degree to which quotas chosen correspond to the projected fishing mortality rate has been questioned even for some developed country fisheries. Still more serious in their effect is the degree to which subsequent exploitation rates can be maintained with the quotas allocated, without politico-economic considerations being allowed to stretch the quotas proposed by fishery scientists.

88. A number of authors have shown the advantages of fixing the level of fishing effort as opposed to fixing catch quotas. It has been noted that if harvesting for sustained yield is the management strategy, environmental perturbations will cause more serious departures from equilibrium conditions than when a constant effort strategy is followed.

2. Management by direct fishing-effort control

89. This strategy corresponds to one of fishing-effort control aimed at a target F- value, usually under some system of limited entry. Early criticisms of this approach were that problems of restraining increases in catchability attributable to learning by skippers and as well as those attributable to technological improvements to boats and gear both lead to creeping increases in fleet fishing power. One disadvantage seen in the early optimistic days of quota control was that, under effort control, catches would vary more widely from year to year than with TAC management, but this is still more desirable than stock collapse. Other more valid objections relate to pelagic stocks such as herring where vulnerability to fishing increases at low stock sizes, so that the fishery can enter an unstable area unless some limiting LRP is applied, as in the case of the constant escapement strategy. The objections to direct effort control need to be reassessed in the light of recent failures of quota control. Effort control measures have the virtue, especially for poorly documented straddling stocks, of providing more stable rate of exploitation and less need for drastic year-to-year renegotiation of management targets than quota control.

3. Management with a constant escapement policy

90. Salmon management has classically been based on attempting to achieve a minimum escapement to spawning, and many such fisheries in western North America aim for fixed escapement objectives. A similar approach has been adopted for some straddling squid fisheries. Such a management approach is compatible with spawning biomass reference points.

VII. CONCLUSIONS

91. Fishery managers, whether they operate in relation to fixed reference points or in relation to less clearly defined criteria, should be recognized as acting in an uncertain environment with incomplete information on which decisions can be taken. As such, the present paper strongly recommends that clear objectives be formulated by all participants and that all uncertainties, whether attributable to the institutional structure or environmental or statistical variability, be recognized and explicitly incorporated into the decision-making process, leading to risk-averse management policies.

92. The paper distinguishes between two different uses of reference points: as targets for management, and as limits beyond which fishing intensity (measured as fishing mortality) should not go. This second framework is believed to be closely compatible with precautionary approaches and by explicitly recognizing the informational inadequacies, allows a new target for management to be defined in relation to this limit.

93. Essential to the effectiveness of this approach, however, is that once the best estimate of the current rate of fishing equals or approaches the limit reference point a pre-negotiated management response should be triggered which significantly reduces the current level of fishing mortality to which the stock is subject.

94. The level of fishing mortality that corresponds to MSY conditions, as usually formulated, is not a generally acceptable target for fisheries management. It may, however, with other reference points such as F_{MAX}, still be useful as a limit reference point for fishing, allowing a lower rate of fishing to be defined from statistical considerations that ensures that this upper limit is rarely exceeded. The paper suggests a framework for such procedure.

95. Judging from FAO and other sources, the current situation of global fish stocks is of full exploitation or overexploitation of many of these under the impact of overcapitalized fleets. Straddling and highly migratory resources have received the impact of effort displaced from more carefully regulated national fisheries, and in many cases are in need of stock rebuilding. Under these conditions reference points that lead to stock rebuilding are believed to be appropriate, and a number of these based on economic, reproductive, stock production and ecological interactions are available, which should lead to stock rebuilding if all participants in the fishery cooperate to ensure that information is adequate to define stock status.

96. It is stressed in the paper that a risk-averse approach would be one seeking to define overfishing in relation to not one, but multiple reference points, for a fishery operating under common technical criteria. Such a suite of reference points could allow for errors in misinterpretation resulting from criteria based on one source of data only.

97. Although the issue of the appropriate management approach to take in straddling and highly migratory stock management goes beyond the scope of the present paper, it is questionable whether any fisheries management framework that attempts to operate by reference to any of the reference points mentioned in this paper will have a significant chance of success under free and open access to all interested participants.

Annex I

RP	Theoretical basis	Data needs	Advantages	Disadvantages	As TRP	As LRP	SR
F_{MSY}	Production model (refer paras. 27 to 33)	Annual data series for yield + calibrated effort for all stock removals	Well-studied: estimates and Y,f series available for many fisheries	High danger of overfishing as TRP	N	YY	N
F_{MCY}	Simulation from Annual recruitment series (refer para. 34)	Probability distribution of annual recruitment and population parameters	In theory, allows quota management with threshold	Data-intensive (needs data on recruitment viability)	Y	N	Y
$2/3F_{MSY}$	Production model (refer paras. 32 and 35)	A production model is assumed fitted	Simply calculated if production model exists	Empirical: requires historical data on Y and standard f/F	Y	N	Y?
$F_{0.1}$	Y/R calculation and current state of population? (refer paras. 37 to 39)	Population parameters	Well-studied: simple to calculate from population parameters	Empirical: varies with fishing strategy; no allowance for recruitment variation	Y	N	Y?
Z_{MSP}	Production model (refer para. 41)	Annual data series of standard catch rate and Z	Incorporates predation; requires simple historical data on CPUE; Z	In present form assumes Schaefer model	Y	N	Y?
Z^{a}	Simulate overall mortality at age and mean size caught (refer para. 61)	Population parameters; mean mortality rate in population and mean size caught	Simply calculated from basic population parameters	Needs unbiased data on size, frequency of catch	N	Y	N
F_{LOW}	Estimate F giving 90 per cent of years with stock replacement (refer para. 44)	Assumes data for fitting stock recruitment (usually from cohort analysis)	Reflects past probability of recruitment	Needs historical data on stock recruitment	Y?	N	Y
F_{MED}	Estimate F giving 50 per cent of years with stock replacement (refer para. 44)	-	-	-	Y	N	N
F_{HIGH}	Estimate F giving 10 per cent of years with stock replacement (refer para. 44)	-	-	-	N	Y	N
$F_{SSB/R}$	Biomass/recruit analytic model (refer para. 45)	Population parameters and maturity-at-age data	Simple to calculate; flexible (depends on percentage)	No major problems	Y	Y	Y
F>=M	Empirical experience with fisheries for similar resources (refer para. 40)	Data on exploitation/natural mortality rates which have proved sustainable	For top predators. Low data needs (just estimate of M)	M values inaccurate. An empirical approach	N	Y	N
F<M	As above (for small pelagics) (refer para. 40)	-	For small pelagics. Low data needs (just estimate of M)	-	Y	N	N
F_{MEY}	Econometric modelling (refer paras. 46 to 50)	Historical data on yield/effort/costs and earnings	Can use production model fit plus cost/revenue data	Hard to define for multiple fleets/economic systems: varies with economic indicators	Y	N	N

[a] RP = reference point; Y = yes; YY = favoured; N = no; LRP = limit reference point; TRP = target reference point; SR = for stock rebuilding; CPUE = catches per unit effort (see text).

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Annex II

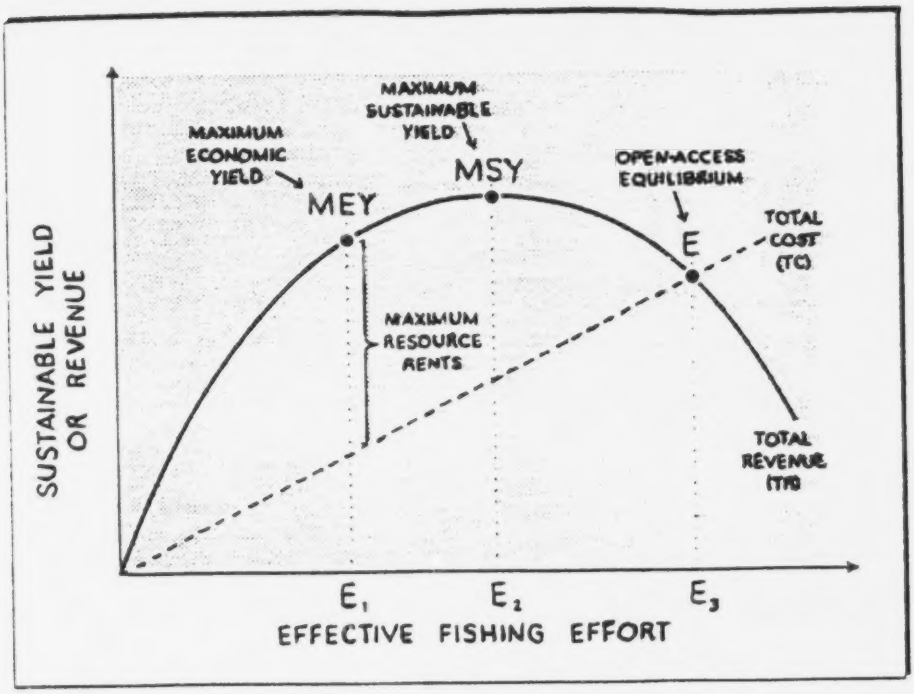
Some likely magnitudes of errors for quantities used in assessing the status quo of shelf fisheries (c.v. = coefficient of variation = 1 standard deviation/mean value*)

Variable	Data source	C.V. values (ranges)	Remarks
Annual catch	Commercial statistics	> 10%	Significant bias (discards/misreporting)
Commercial Catch rate	"	around 10%	" "
Catch-at-age	"	" 10%	
Survey for biomass	trawling	36 - 41%	Improves with repetition (more stations sampled)
" "	acoustic (small pelagic fish)	26 - 35%	" " "
Fishing mortality rate	cohort analysis etc.	10 - 30%	
Natural mortality rate (M)	catch curves, etc.	(indefinite)	Many assessments employ values developed for other stocks

* There is an 85 per cent chance that the variable lies within 1 standard deviation of its mean value: thus, if for the biomass, the c.v. = 30 per cent and mean value is 100 t, there is an 85 per cent chance that the mean lies between 70 and 130 t.

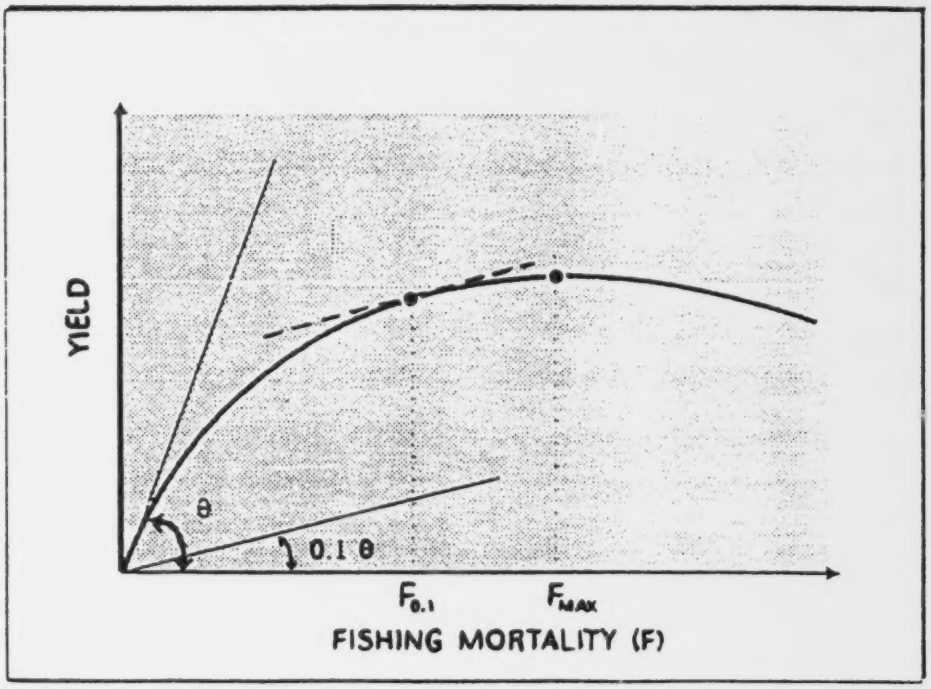
Annex III

The Graham-Schaefer equilibrium production curve relating yield or revenue to effective fishing effort and showing three Reference Points: MEY, MSY and the bionomic equilibrium point E; these occur at progressively higher levels of fishing effort.



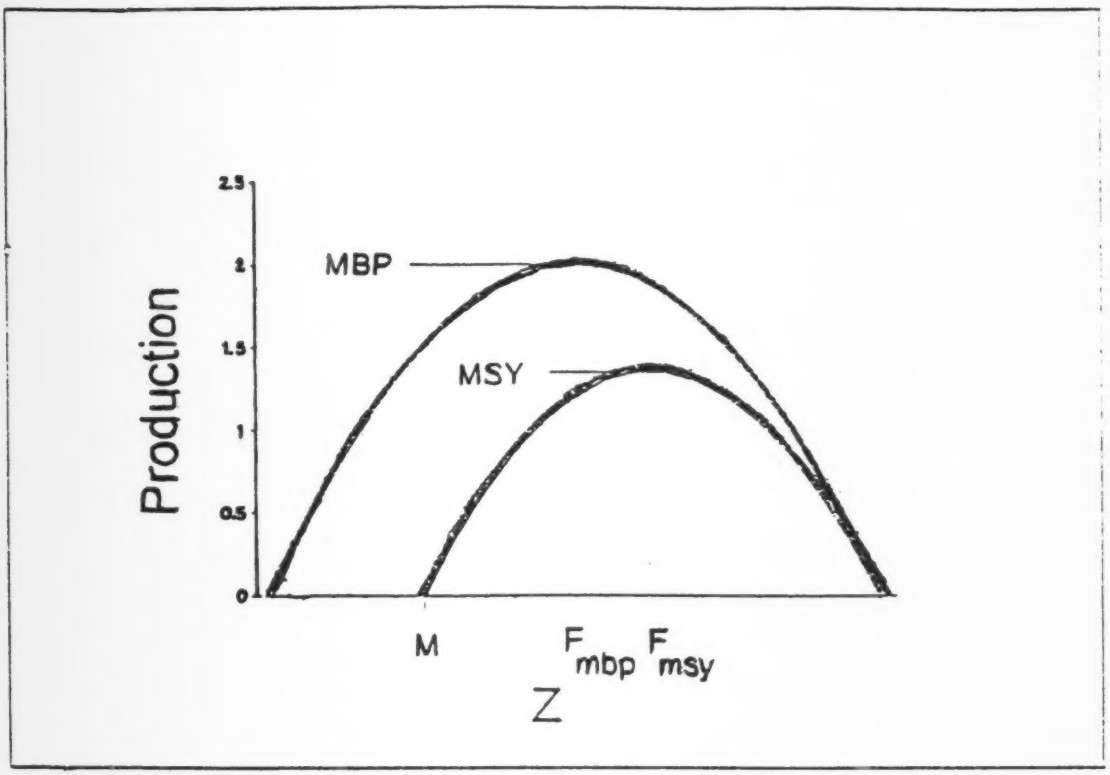
Annex IV

Illustration of the method used to define $F_{0.1}$, given a known relationship between the fishing mortality rate and yield (or more strictly, yield/recruit), as the tangent to the curve for a straight line with a slope 1/10 of the initial rate of increase in yield/recruit



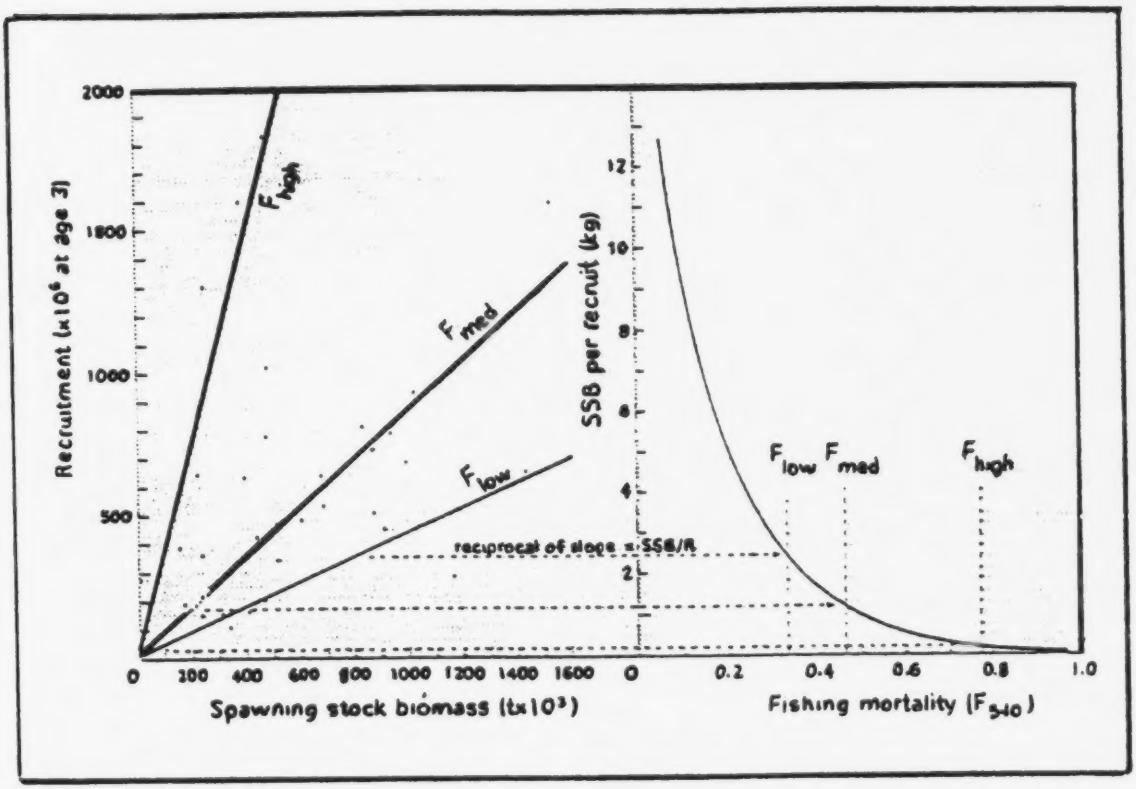
Annex V

Illustration for the equilibrium of the Schaefer model, the relationship between MSY, Z and the fishing rate corresponding to the maximum biological production (MBP) for a stock (for which $F_{MBP} < F_{MSY}$)



Annex VI

Illustration of the definition of F_{LOW}, F_{MED} and F_{HIGH} in the case of the Northeast Arctic cod stock



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Annex VII

USING A LIMIT REFERENCE POINT TO SET A RISK-AVERSE RATE OF EXPLOITATION - THE F_{MSY} EXAMPLE

There may be circumstances when fisheries managers are able to specify an upper limit to fishing intensity, beyond which an undesirable state of the fishery is agreed to exist. As noted in the main document, this may be referred to as an LRP. In the following example it is assumed that the LRP is a pre-established "conventional" value for the fishing mortality corresponding to MSY conditions, agreed by all parties.

The managers acknowledge that they are operating in an uncertain environment and that the current "status quo" for the fishery, together with the F-value during the last season ($=F_{NOW}$), was not precisely known, but that some rough estimates of its standard deviation can be made. In the hypothetical case in question, there is strong evidence that the fishing intensity last year was below F_{MSY}, and it is assumed that if the same effort were to be exerted in the next season, it could be expected that the probability distribution of fishing mortality rates would remain the same. The managers feel however that it would be useful to define a target reference point in such a way that this results in a small, pre-specified risk that F_{MSY} is not exceeded.

Given this situation, the following illustrates one procedure for calculating appropriate target values for F_{NOW} which result in a pre-specified probability of an agreed LRP being respected. In this example, the LRP is assumed to be a pre-established value for $F_{MSY}=0.6$. There is no unambiguous evidence in the literature as to the most appropriate distribution function describing the uncertainty in the current value of F, but as a first reasonable choice the normal distribution is used (see the figure below), although similar calculations could readily be performed for other distribution functions.

Mathematically, the procedure adopted is the following: the level of the fishery can safely tolerate (quantified in the figure below as the shaded area on the right-hand tail of the normal distribution) is equivalent to the probability that the current F exceeds the target reference point, F_{NOW}. Referring to this chosen level of acceptable risk as $P\ (F>F_{MSY})$, the mean of the distribution must be resolved; i.e., the value of F_{NOW} that corresponds to the target reference point providing this margin of safety.

A mathematical package (MAPLE) was then used to solve for F_{NOW} for the nine cases presented in the table.

Table A.VII.1

Assuming $F_{MSY} = 0.6$, the following gives indicative values of F_{NOW} that could be used as TRPs for combinations of (columns): the acceptable proportion of the time that $F > F_{MSY}$, and (rows): standard deviation of F.

$P(F_{NOW} > F_{MSY})$	Standard Deviation of F values		
	σ = 0.25	= 0.5	= 1.0
30%	0.53	0.475	0.39
20%	0.50	0.42	0.33
10%	0.45	0.365	0.26

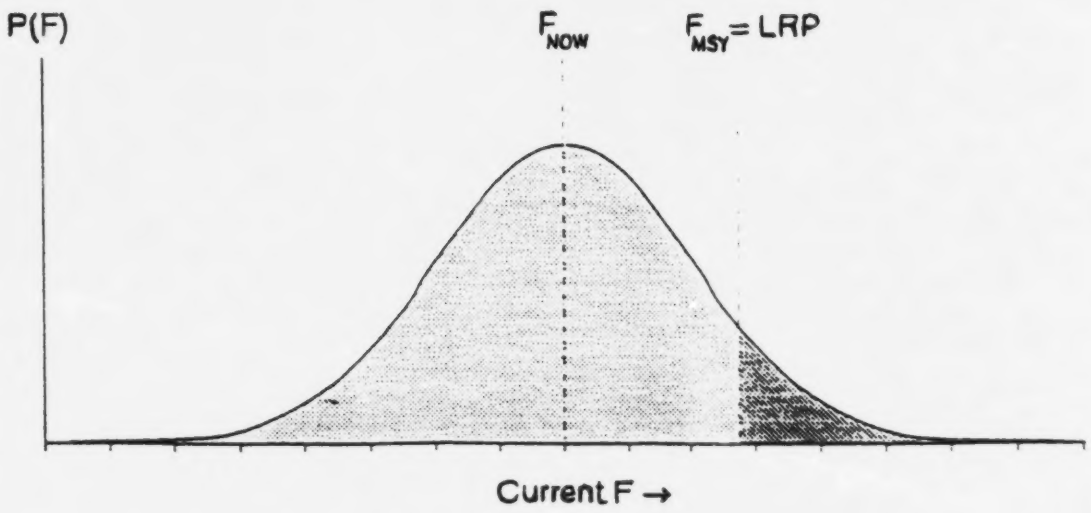

Figure A.VII.1. Illustrating the uncertainty as to the present rate of fishing, F_{NOW}, in relation to a limit reference point (in this case, assumed to be F_{MSY}). A finite probability (P(F) of $F > F_{MSY}$ is represented by the shaded right-hand limb of the normal distribution.

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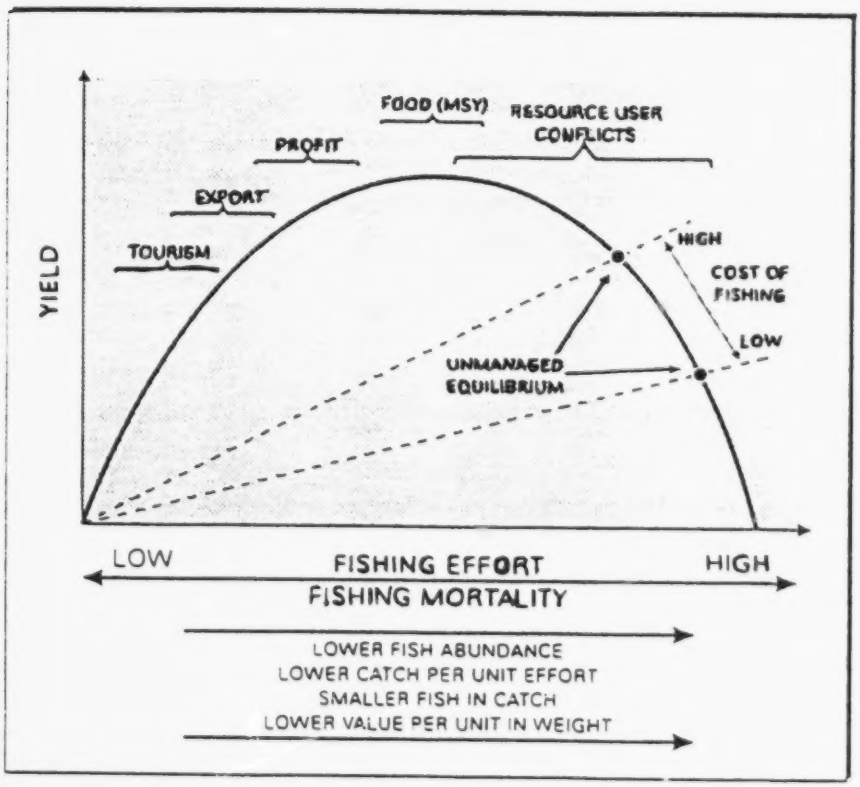
Annex VIII

Some relative ranges for the fishing mortality rate corresponding to different uses of marine resources by society



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HIGHLY MIGRATORY FISH STOCKS
New York, 14-31 March 1994

AD HOC CONSULTATION ON THE ROLE OF REGIONAL FISHERY AGENCIES IN RELATION TO HIGH-SEAS FISHERY STATISTICS

SUMMARY

The Consultation was held at the Headquarters of the Inter-American Tropical Tuna Commission, La Jolla, California, United States of America, from 13 to 16 December 1993. The Consultation reviewed the high-seas statistics presently collated by regional fishery agencies and considered the data requirements for conservation and management of high-seas stocks. In particular, it used annex I of the negotiating text prepared by the Chairman of the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks as the basis for elaborating the minimum data requirements for high-seas fisheries, which are relevant to the conservation of fish stocks as referred to in Article 119 (2) of the 1982 United Nations Convention on the Law of the Sea. Other related issues were also considered. The report of the Consultation is published as FAO Fisheries Report No. 500.

INTRODUCTION

1. The Chairman of the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (the United Nations Conference), Mr. Satya Nandan, participated. Fourteen participants from nine regional fishery agencies attended the Consultation. The Chairman of the Consultation was Mr. James Joseph, Director, Inter-American Tropical Tuna Commission (IATTC).

2. The main purpose of the Consultation was to specify the requirements for statistics on high-seas fisheries for research and management purposes, taking into account confidentiality needs and regional differences, and with particular reference to annex I of the negotiating text prepared by the Chairman of the United Nations Conference. 1/ Other tasks were to describe the statistics on high-seas fisheries routinely collated by various regional fishery agencies, to advise on the high-seas fisheries statistics which should be collated and disseminated by the Food and Agriculture Organization of the United Nations (FAO), and to propose arrangements for the exchange of high-seas fishery statistics and information on the authorization of vessels to fish on the high seas between regional fishery agencies and FAO.

3. Mr. Nandan noted that the deliberations at the Consultation were central to some of the technical issues being addressed by the United Nations Conference and that the collection of high-seas fisheries data was essential as a basis for effective conservation and management of straddling fish stocks and highly migratory fish stocks. He pointed out that the role of regional fishery agencies in relation to this would be crucial.

I. REVIEW OF STATISTICS COLLATED BY REGIONAL FISHERY AGENCIES

4. The activities of regional fishery agencies in relation to the collection and collation of high-seas fishery statistics were reviewed. Most agencies do not compile statistics for high-seas areas separately, although most can estimate the high-seas components by the allocation of statistical rectangles to high-seas zones as an approximation. The proportion of the catches recorded by regional fishery agencies which are from high-seas fisheries varies from almost 100 per cent in the Southern Ocean (Antarctic) to about 2 per cent for non-tuna fisheries in the North-east Atlantic. Most agencies compile data for the purpose of undertaking stock assessment as a basis for the provision of management advice. Although most agencies collate some data on discarded catches of fish and shellfish, the quality and coverage is generally poor. Very few agencies have information on incidental bycatches of birds and marine mammals. The cost to the agencies of conducting their statistical programmes (for exclusive economic zones as well as high seas) varies widely.

5. The Consultation noted that some important high-seas fisheries are not covered at the present time by active fishery agencies. These include the North Pacific (for Alaska pollack), the South-west Atlantic (for hake and squid), the South-east Atlantic (for horse mackerel and cape hakes), the South-west Pacific (for orange roughy), the South-east Pacific (for Chilean jack mackerel) and the

North-west Pacific (for tuna). The Consultation also noted a number of problems affecting regional fishery agencies with respect to high-seas fishery data.

II. REQUIREMENTS FOR STATISTICS ON HIGH-SEAS FISHERIES

6. The Consultation recognized that regional fishery agencies are major users of fishery statistics, both for stock assessment and management purposes, and that they should, in consultation with their members, determine what data are collected.

7. The Consultation welcomed the specification of the roles of regional fishery agencies and flag States in the collection and exchange of data necessary to meet stock assessment requirements and support management objectives as provided in the negotiating text prepared by the Chairman of the United Nations Conference. It particularly welcomed the stipulation of minimum data requirements in annex I to the negotiating text which provides an important specification of the "data relevant to the conservation of fish stocks" as referred to in Article 119 (2) of the 1982 Convention on the Law of the Sea as well as the general data requirements specified by the 1992 FAO Technical Consultation on High Sea Fishing. The negotiating text also takes into account the action and cooperation needed to address the inadequacies in fisheries statistics and data handling systems for the high seas, as noted by the 1992 United Nations Conference on Environment and Development.

8. The Consultation agreed that there was a need to allow flexibility in standards in order to take account of the differing needs by region and species, but that annex I of the negotiating text provided a common framework for specifying standards. It was therefore agreed to use annex I as a basis upon which to elaborate the data requirements.

9. Recognizing the need for adequate data to be collected throughout the range of a stock, the Consultation decided to consider the data requirements for the conservation and management of straddling fish stocks and highly migratory fish stocks as a whole, and not just the requirements for high-seas fishery data. It was considered important that common standards should apply to areas in both the exclusive economic zone and the high seas. The Consultation further agreed that these minimum standards should apply to all flag States, and not just to members of regional fishery agencies.

10. The Consultation recognized that reliable data on discards were essential for proper management and that the current availability of such data was inadequate. The Consultation recommended that discard statistics be collected by States and regional fishery agencies and that, where possible, their collection or validation should be through the use of observer programmes.

11. The Consultation agreed that a minimum statistical requirement should be the provision of nominal catch in terms of weight or numbers of fish, together with factors allowing the numbers to be converted into equivalent weight or vice versa. The nominal catch statistics should be accompanied by discard statistics and both should be specified by species, flag of vessel, gear type, area, time and stock; where specification by stock was not possible, the statistics should

be provided by FAO major fishing area or as close an approximation to it as possible. The time unit used for reporting these nominal catch and discard data should be the calendar year or a shorter time period. For seasonal fisheries traversing two calendar years, the statistics should be provided both in terms of calendar year and fishing season.

12. The Consultation agreed that another minimum statistical requirement was for effort and associated catch data. Effort data were required for three main purposes: (a) assessment analyses as an index of fishing mortality and for deriving abundance indices, (b) economic analysis and (c) management purposes. For effort and associated catch data, a finer level of spatial and temporal detail was required than for the nominal catch and discard statistics.

13. The Consultation agreed on a classification of fishing gears and associated units of effort. Five levels of priority were specified, each with different effort descriptors, depending on data availability. The catch (fish and non-fish) associated with the effort should be reported as nominal catch in terms of weight or numbers, together with appropriate conversion factors and with corresponding data for discards. Catches should be classified as retained catch or discards. The catch data by species and associated effort should be reported by flag of vessel, vessel size class, gear type, area and time. Where regional fishery agencies existed, they should specify the resolution of the data to be provided. For other areas, States should adopt criteria based on the resolution used by regional fishery agencies in adjacent areas and for similar stocks.

14. Owing to the complexities and difficulties in defining, collecting and interpreting economic data, the Consultation did not have sufficient time to consider this matter in detail. It was recommended that FAO should have the question of requirements for economic data investigated in an appropriate forum involving regional fishery agencies.

15. The Consultation believed that biological data were essential for stock assessment purposes and should be included in the minimum requirements. It was agreed that length compositions or weight compositions with associated weight/length conversion information for retained and discarded components of each species should be included in the minimum requirements. For some stocks or species, additional data, including sex, age and maturity compositions, were required for assessment purposes, and in such cases those data should also be included within the minimum requirements. The provision of biological parameters supporting stock assessments and the undertaking of other relevant research, including tagging experiments, surveys of abundance, biomass surveys, hydro-acoustic surveys, research on environmental factors affecting stock abundance and oceanographic and ecological data were also considered very important.

16. The importance of vessel data for management purposes was recognized. The Consultation agreed that the minimum requirements for data on all vessels fishing on the high seas, irrespective of size, should include, as essential, the items specified in the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High-seas ("the Flagging Agreement"), under Article VI, paragraph 1.

17. The Consultation also agreed that the items listed in paragraph 2 of the same article should be provided to the extent practicable. In addition, it was agreed that the fish preservation method (freezing in brine, drying, etc.), the hold capacity (in cubic metres), the rated speed (in knots) and the vessel marking (as referred to in article III, paragraph 6, of the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas) should also be included in the list of items to be provided to the extent practicable.

III. LOGISTICAL AND FINANCIAL IMPLICATIONS ASSOCIATED WITH DATA COLLECTION

18. States and regional fishery agencies have clearly established policies and standards with respect to maintaining the confidentiality of catch and related data, which is essential to maintain the full cooperation of industry and national statistical reporting offices and to ensure the reliability of data. The Consultation agreed that the primary responsibility for ensuring confidentiality of data provided to FAO should remain with the national authorities and regional fishery agencies.

19. The Consultation agreed that verification of data supplied on high-seas fisheries is essential. For fisheries subject to management, it was desirable to have real-time data, and the importance of data transmission by radio, facsimile or transponders installed on fishing vessels was recognized.

20. The Consultation noted that in some cases developing coastal States lacked the financial and technical resources to collect reliable fishery statistics. In such cases the international community was called upon to assist those States financially and/or technically to develop the capability to collect such information.

21. The Consultation agreed that every effort should be made to ensure that the current statistical reporting requirements of regional fishery agencies and FAO were met. These requirements were that: (a) nominal catch data should be compiled and submitted to regional fishery agencies and/or FAO with no more than a six-month time lag, and (b) effort and associated catch data should be submitted with no more than a nine-month time lag. These time limits referred to the submission of data for statistical purposes and not for fisheries management control purposes.

IV. HIGH-SEAS FISHERIES STATISTICS TO BE COLLATED BY FAO

22. The 1992 Technical Consultation on High Seas Fishing considered that FAO could coordinate the compilation of aggregated data for high-seas fishing. Such aggregated data would serve three main purposes, in that it would (a) provide a basis for describing fishing activity taking place on the high seas, (b) serve to describe global trends in high-seas fisheries and (c) indicate how effort might shift from one fishery to another in response to changes such as fishery restrictions. The Consultation agreed that catch and effort data should be

provided to FAO on a stock basis, subdivided into high-seas and exclusive-economic-zone components, and where possible on a finer scale.

23. The regional fishery agencies concerned with tuna generally collect more reliable fishery statistics for the catch and effort of tuna vessels than are held at national level. Because FAO will require data identified separately for the high seas, and because the most meaningful aggregation would be at the stock level, the Consultation recommended that for tuna and tuna-like species, regional fishery agencies should provide FAO with nominal catch, discard and effort data by species, stock area, FAO major fishing area (this will in some cases be an approximation), inside/outside the exclusive economic zone, gear type and year. The effort unit would be that considered most appropriate by the regional fishery agency. The stock area would correspond to that recognized by the agency and would be specified in terms of 5°x 5° rectangles.

24. For other species, FAO could request corresponding catch and effort data for straddling stocks from regional fishery agencies where they existed. These data should be defined in terms of the agency's statistical divisions. Many areas are not covered by active regional agencies, so this would necessitate FAO requesting data directly from national sources.

V. EXCHANGE OF INFORMATION CONCERNING THE AUTHORIZATION OF VESSELS TO FISH ON THE HIGH SEAS

25. The Consultation welcomed the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, approved by the Twenty-seventh Session of the FAO Conference in November 1993, and stressed the importance for all States whose vessels fish on the high seas to accede to it.

26. The Consultation acknowledged that FAO would provide regional fishery agencies with a list of vessels authorized to fish on the high seas, subject to any restrictions imposed by contracting parties providing the information as specified in the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas. Similarly, the Consultation agreed that agencies should, where possible, provide FAO with a list of vessels operating within their respective Convention areas. In this way both FAO and the regional fishery agencies would be in a position to compare vessel lists and detect discrepancies.

27. The Consultation further agreed that regional fishery agencies should exchange information among themselves concerning non-party vessels known to be fishing in the Convention areas of other regional fishery agencies.

Notes

1/ A/48/479, annex II; originally issued as A/CONF.164/13.